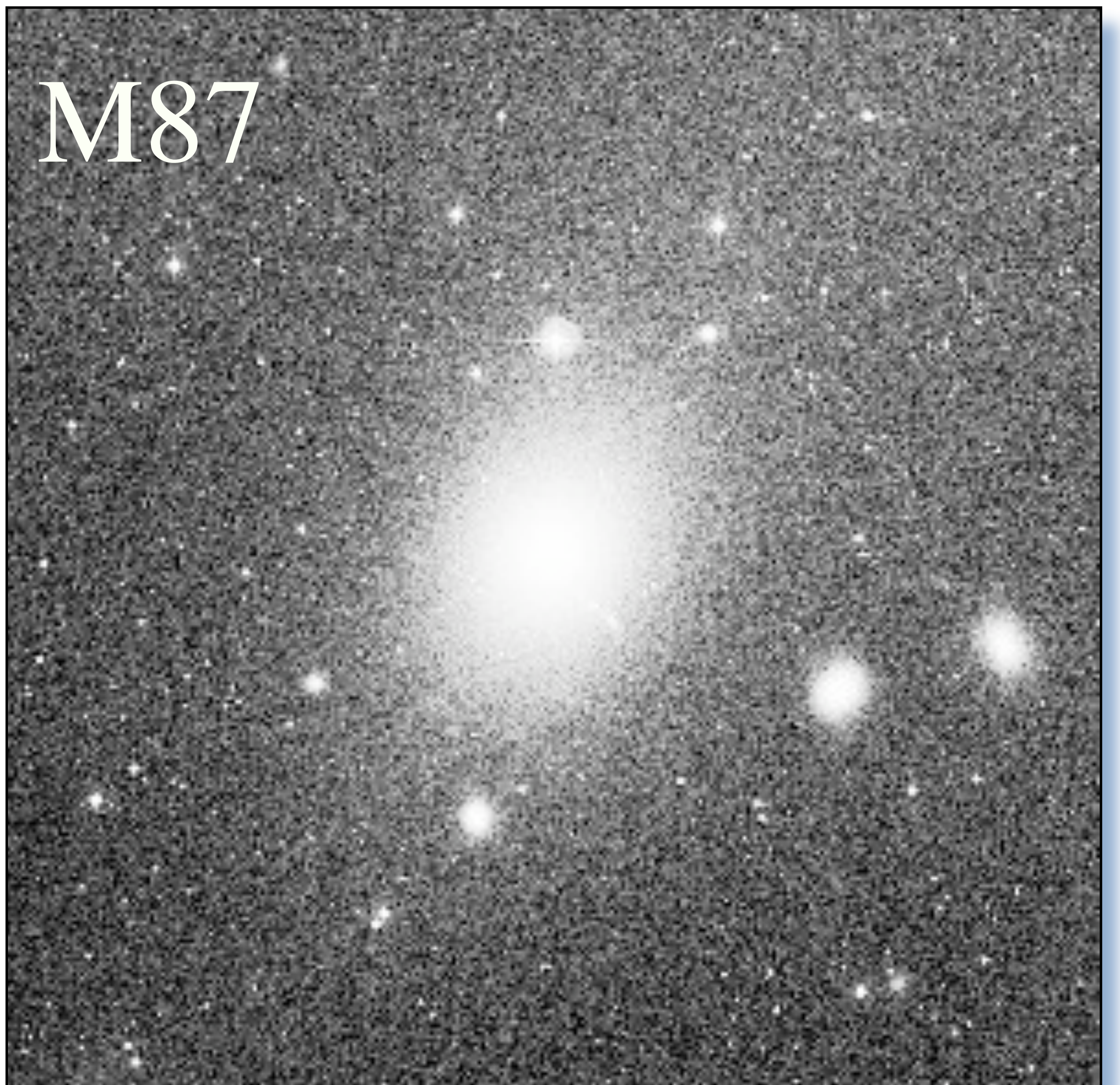
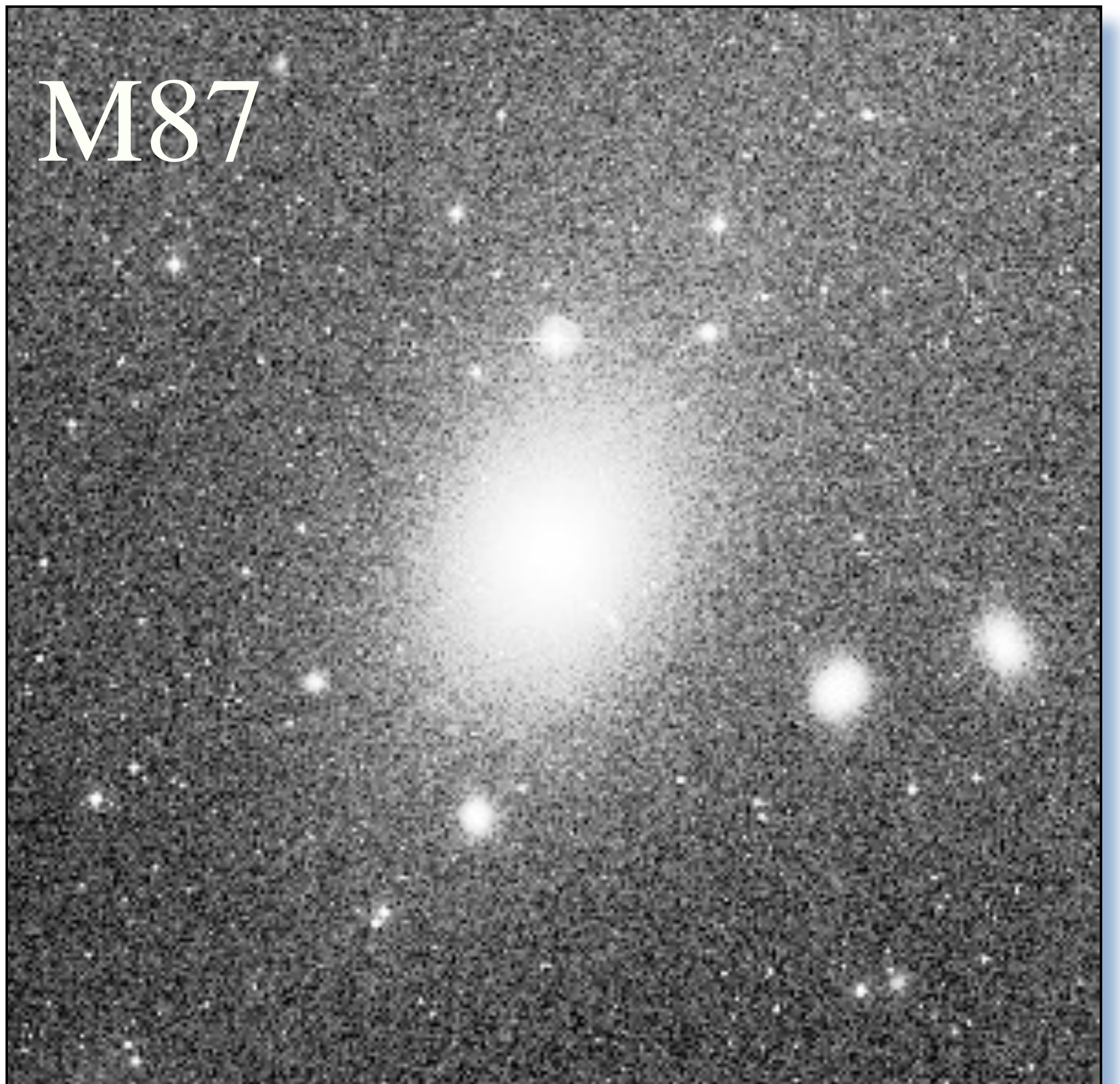
A Revised Perspective on Galactic Structure

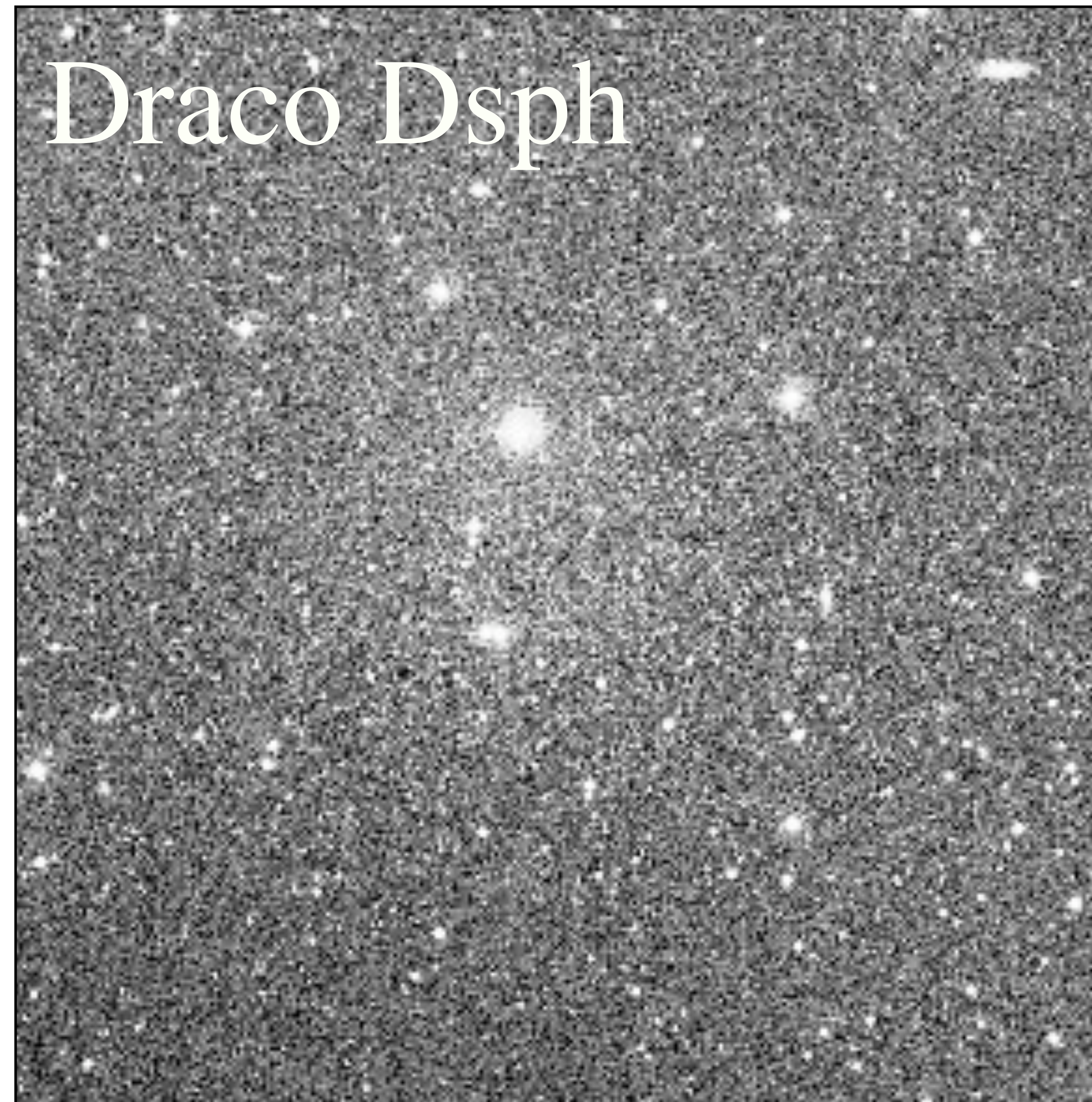


Dennis Zaritsky
(Univ. of Arizona)

with Ann Zabludoff and Anthony Gonzalez

A Revised Perspective on Galactic Structure





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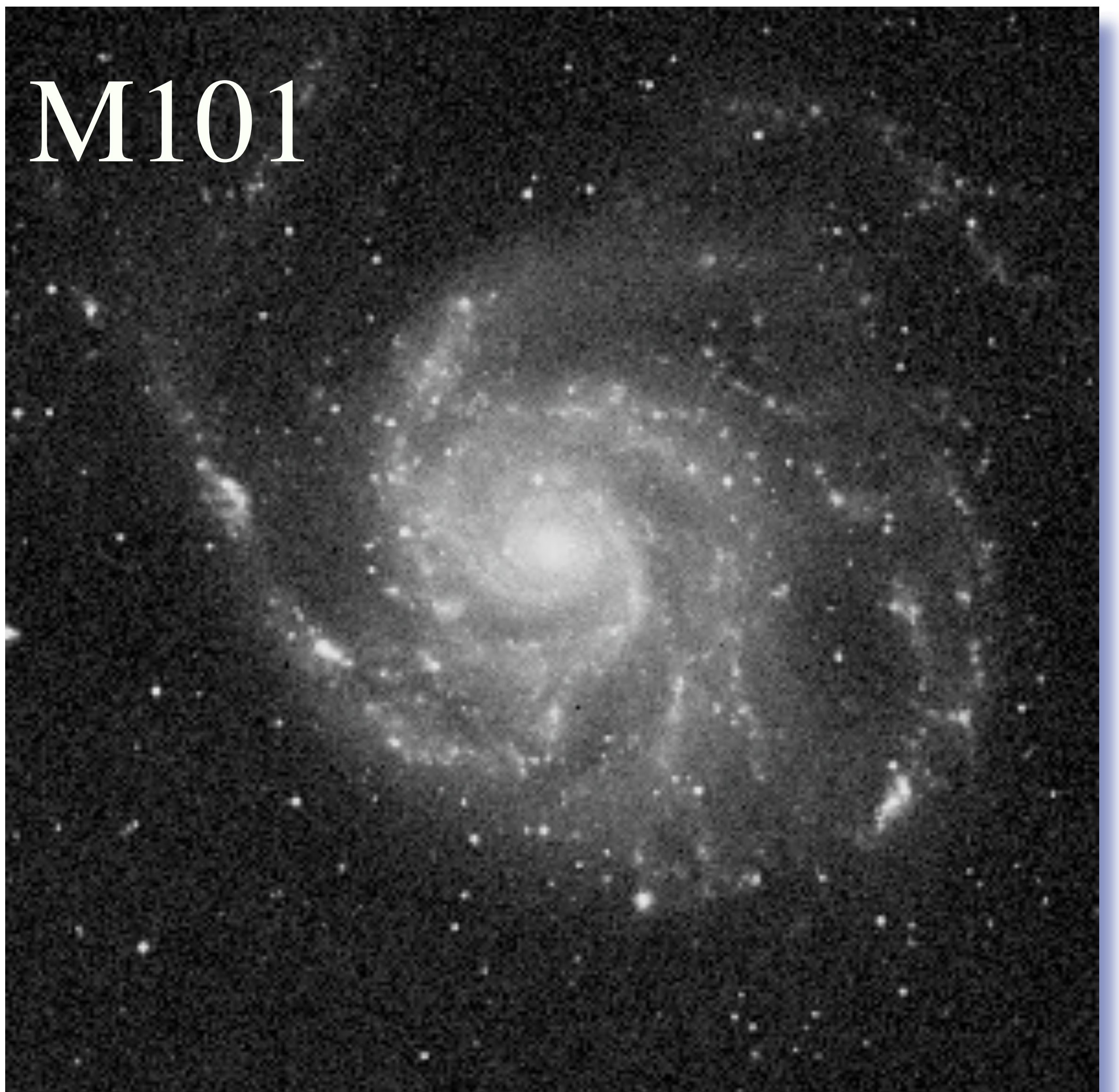
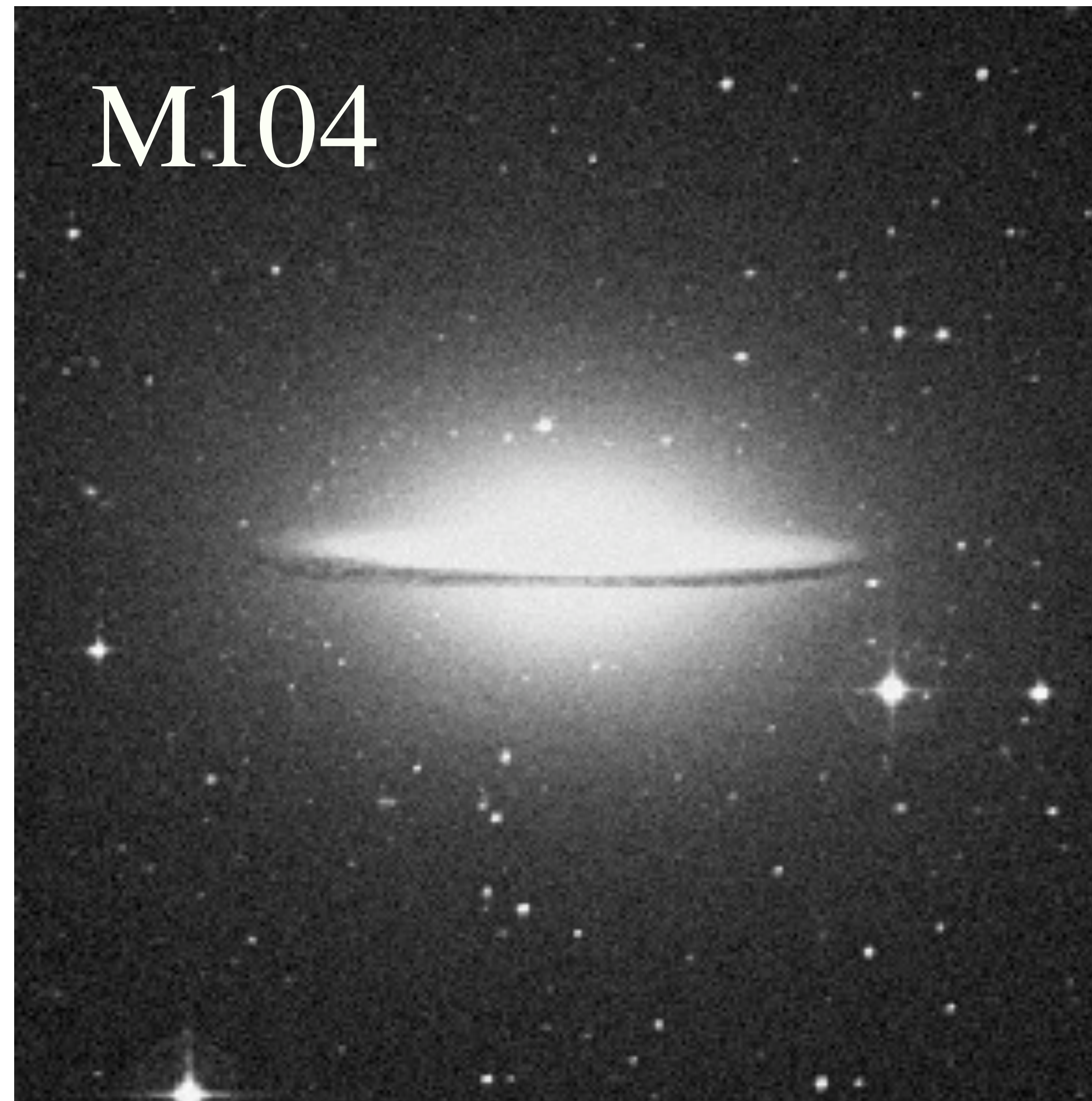
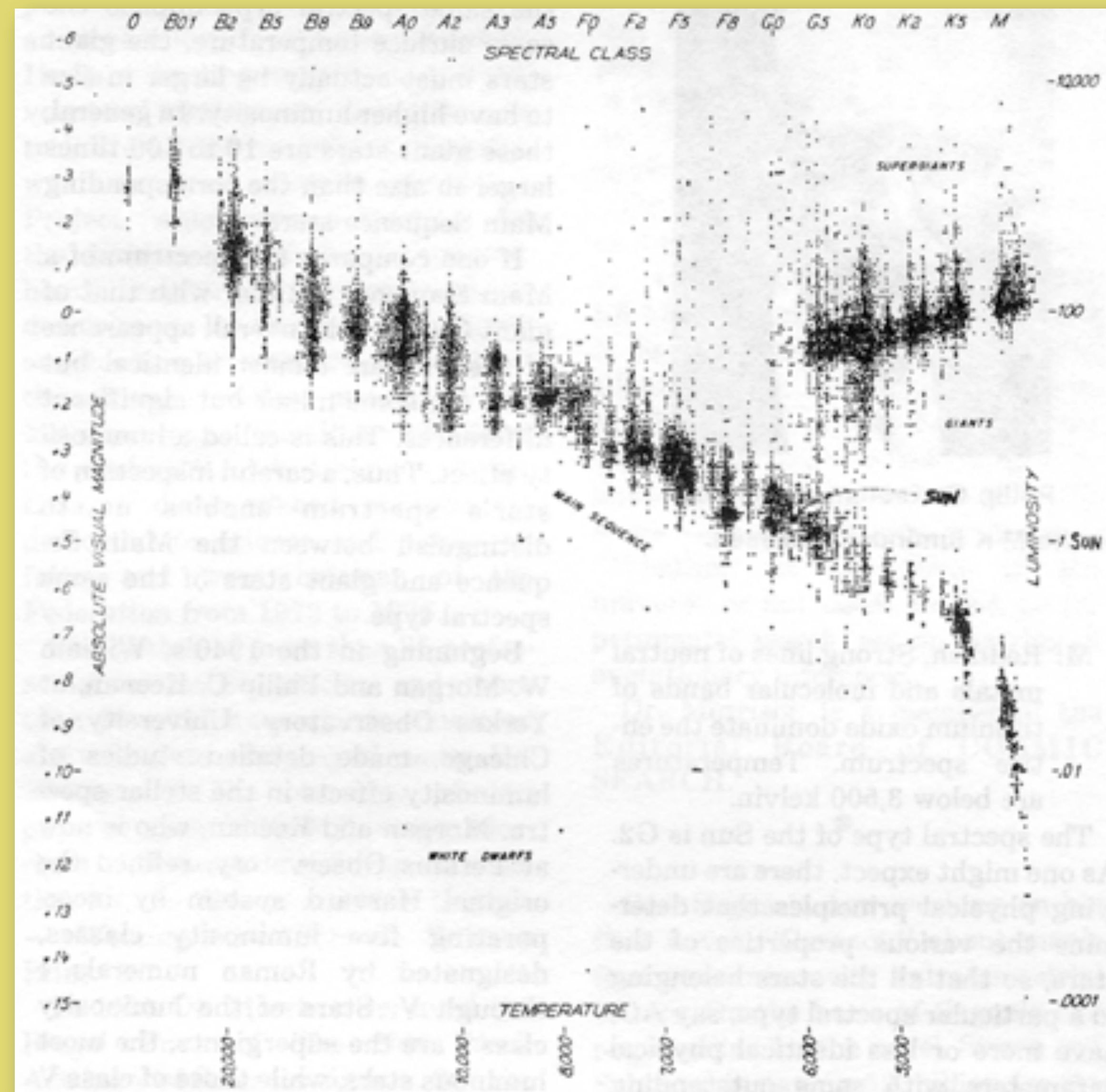




Are the rules simple or complicated?

Lessons from Stellar Structure



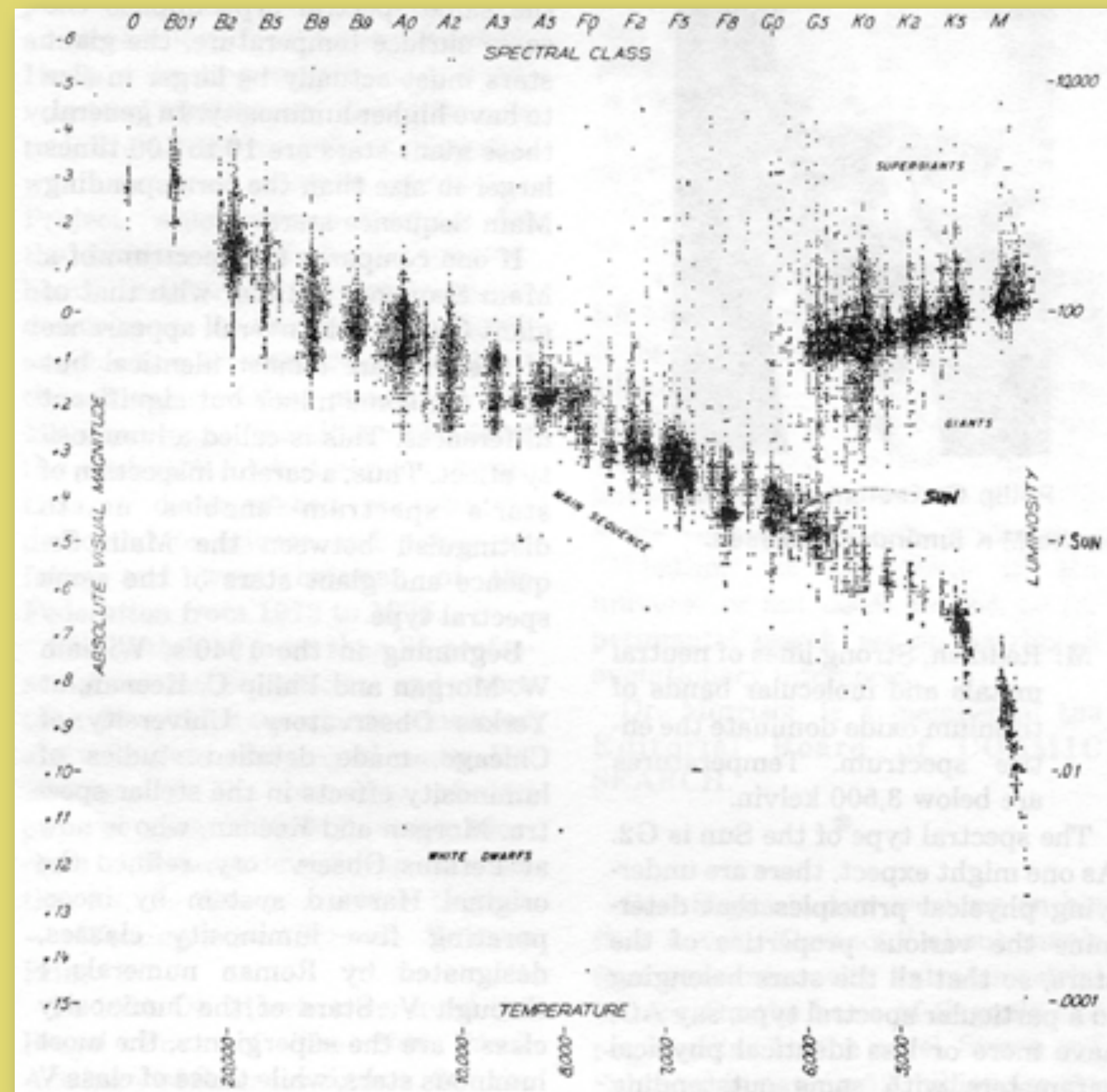
luminosity

spectral type or color

Lessons from Stellar Structure

Equilibria identified

luminosity



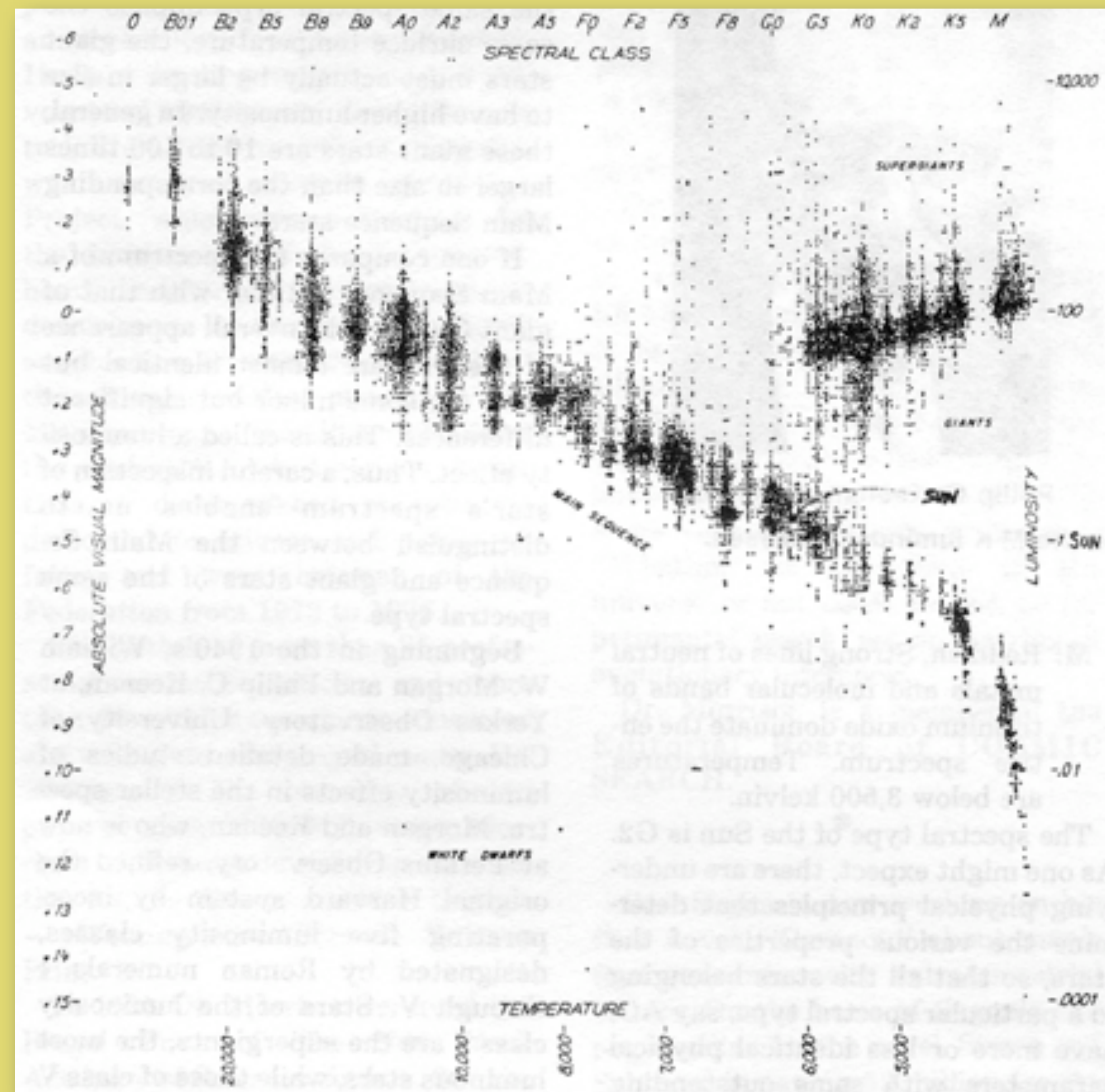
spectral type or color

Lessons from Stellar Structure

Equilibria identified

1-D sequence in 2-D space implies one driving parameter

luminosity



spectral type or color

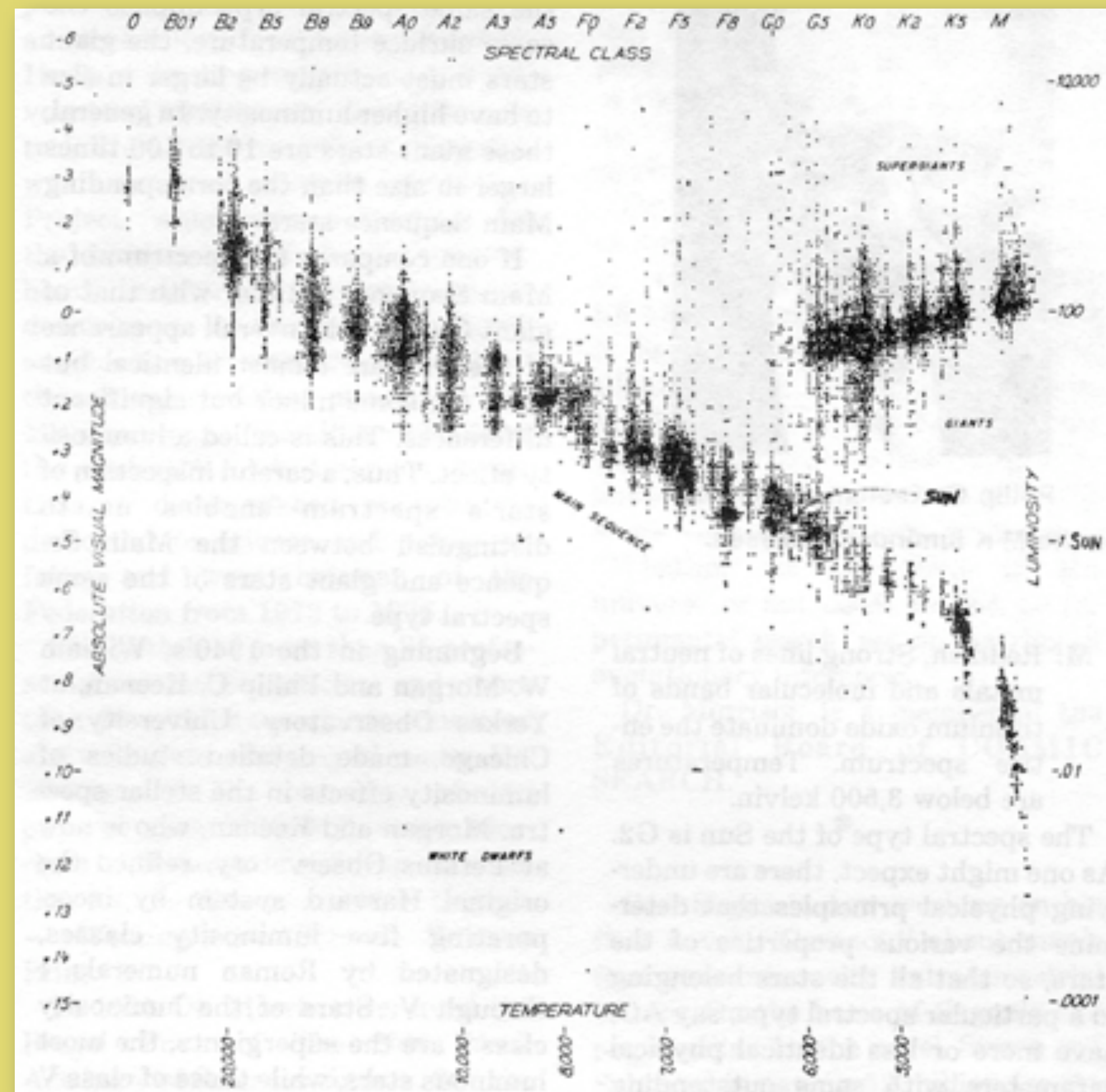
Lessons from Stellar Structure

Equilibria identified

1-D sequence in 2-D space implies one driving parameter

Problem of structure separated from that of formation

luminosity



spectral type or color

on to galaxies...

starting with what we know: Tensor Virial Theorem

$$2T + \Pi + W = 0$$

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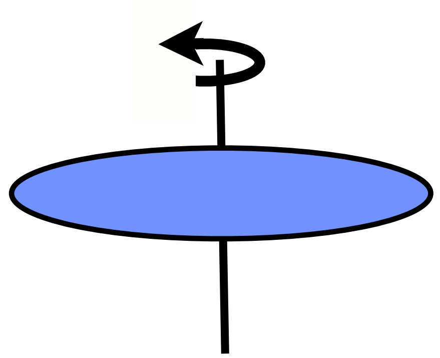
$$2T + \Pi + W = 0$$

$$\sum_i v_i^2 = A_0 v_{rot}^2$$



on to galaxies...

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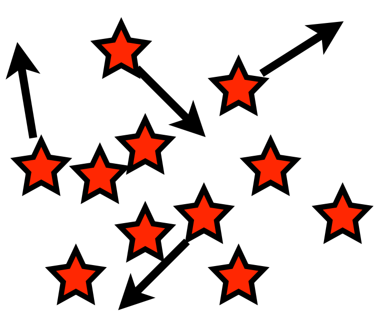
$$2T + \Pi + W = 0$$

$$\sum_i v_i^2 = A_1 \sigma^2$$

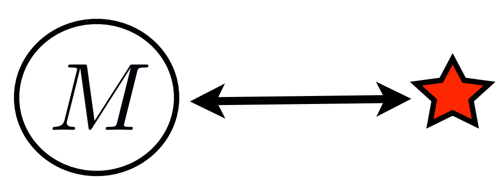


on to galaxies...

starting with what we know: Tensor Virial Theorem

$$2T + \Pi + W = 0$$

$$\sum_{ij} \frac{G m_j}{r_{ij}} = B_0 \frac{M}{r_{1/2}}$$



on to galaxies...

starting with what we know: Tensor Virial Theorem

$$2T + \Pi + W = 0$$

$$A_0 v_{rot}^2 + A_1 \sigma^2 = B_0 \frac{M}{r_{1/2}}$$

on to galaxies...

starting with what we know: Tensor Virial Theorem

$$2T + \Pi + W = 0$$

$$M = C\pi r_{1/2}^2 I_{1/2} \Upsilon_{1/2}$$

$$A_0 v_{rot}^2 + A_1 \sigma^2 = B_0 \frac{M}{r_{1/2}}$$

on to galaxies...

starting with what we know: Tensor Virial Theorem

$$2T + \Pi + W = 0$$

$$A_0 v_{rot}^2 + A_1 \sigma^2 = B_0 \frac{M}{r_{1/2}}$$

$$A\left(\frac{v_{rot}^2}{2} + \sigma^2\right) \equiv AV^2$$

on to galaxies...

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on to galaxies...

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$$A_0 v_{rot}^2 + A_1 \sigma^2 = B_0 \frac{M}{r_{1/2}}$$

$$AV^2 = B \frac{\pi r_{1/2}^2 I_{1/2} \Upsilon_{1/2}}{r_{1/2}}$$

on to galaxies...

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$$2T + \Pi + W = 0$$

$$A_0 v_{rot}^2 + A_1 \sigma^2 = B_0 \frac{M}{r_{1/2}}$$

$$AV^2 = B \pi r_e I_e \Upsilon_e$$

on to galaxies...

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$$AV^2 = B \pi r_e I_e \Upsilon_e$$

$$\log r_e = 2 \log V - \log I_e - \log \Upsilon_e + \log A - \log B$$

moving on to what we can learn ....

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$$\log r_e = 2\log V - \log I_e - \log \Upsilon_e + \log A - \log B$$

directly observable

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Upsilon_e + \log A - \log B$$

quasi-observable

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Upsilon_e + \log A - \log B$$

completely unobservable, but encapsulates most of the interesting astrophysics

moving on to what we can learn ....

$$\log r_e = 2 \log V - \log I_e - \log \Delta$$

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Delta$$

a simple option is

$$\log r_e = 2\log V - \log I_e - \log f(V, I_e)$$

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Delta$$

a simple option is

$$\log r_e = 2\log V - \log I_e - \log f(V, I_e)$$

the simplest (non-trivial) option is

$$\log r_e = 2\log V - \log I_e - \log(V^{\alpha} I_e^{\beta}) + C$$

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Delta$$

a simple option is

$$\log r_e = 2\log V - \log I_e - \log f(V, I_e)$$

the simplest (non-trivial) option is

$$\log r_e = (2-\alpha)\log V - (1+\beta)\log I_e + C$$

(otherwise known as the fundamental plane)

moving on to what we can learn ....

$$\log r_e = 2\log V - \log I_e - \log \Delta$$

a simple option is

$$\log r_e = 2\log V - \log I_e - \log f(V, I_e)$$

moving on to what we can learn ....

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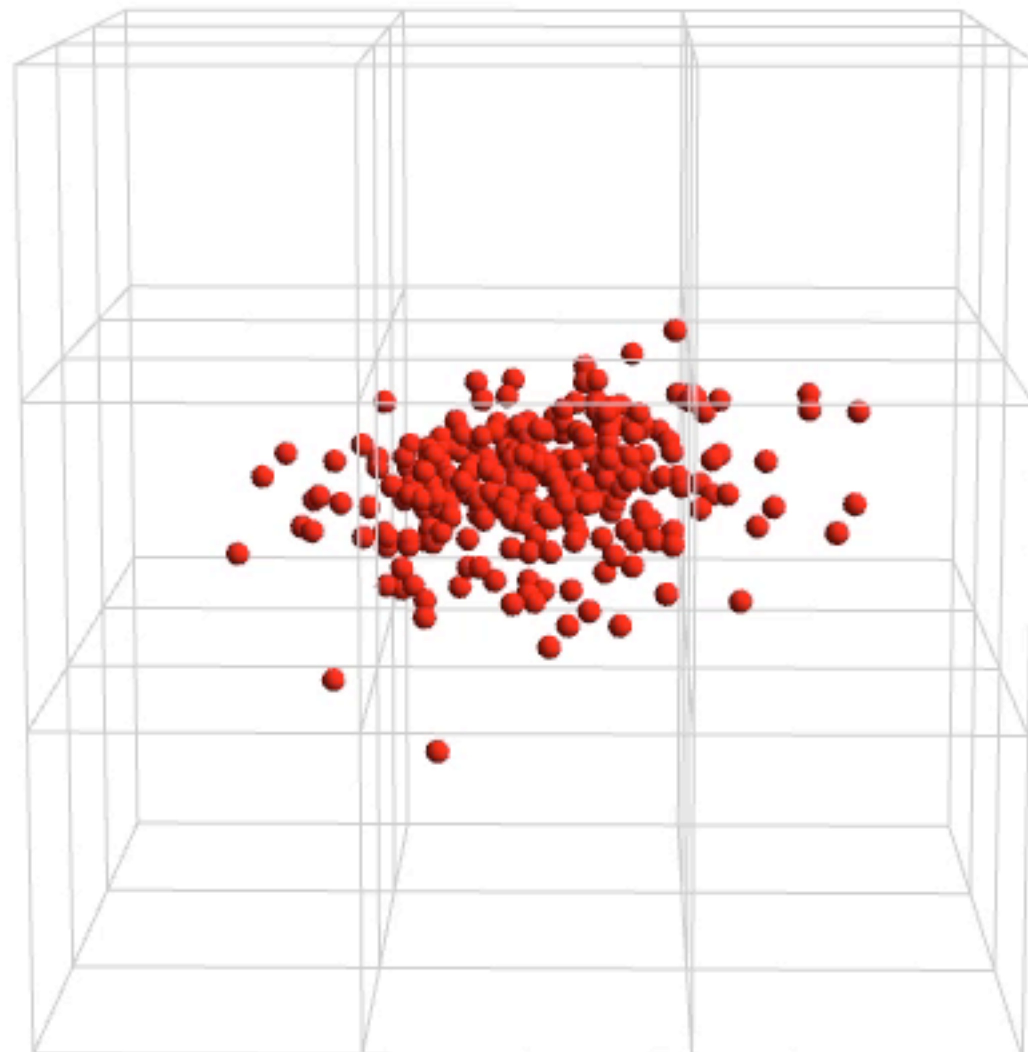
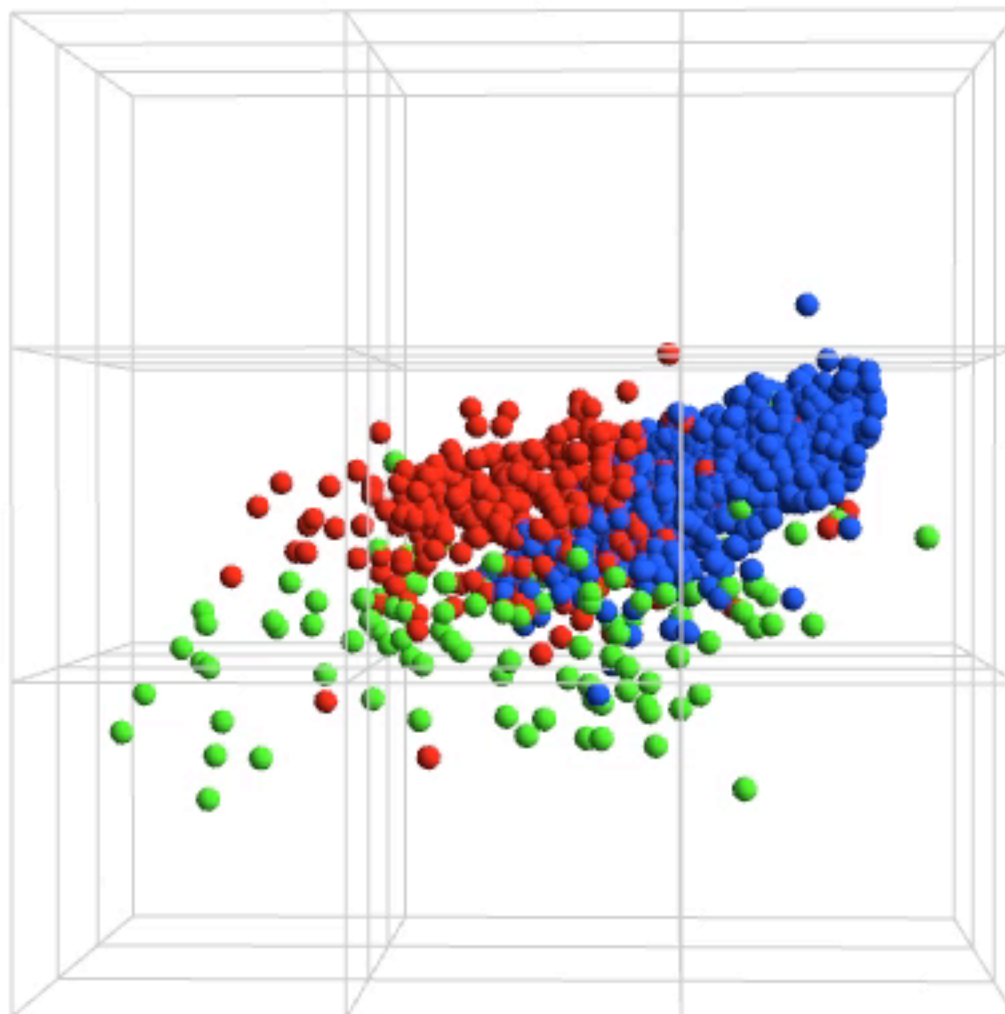


normal ellipticals

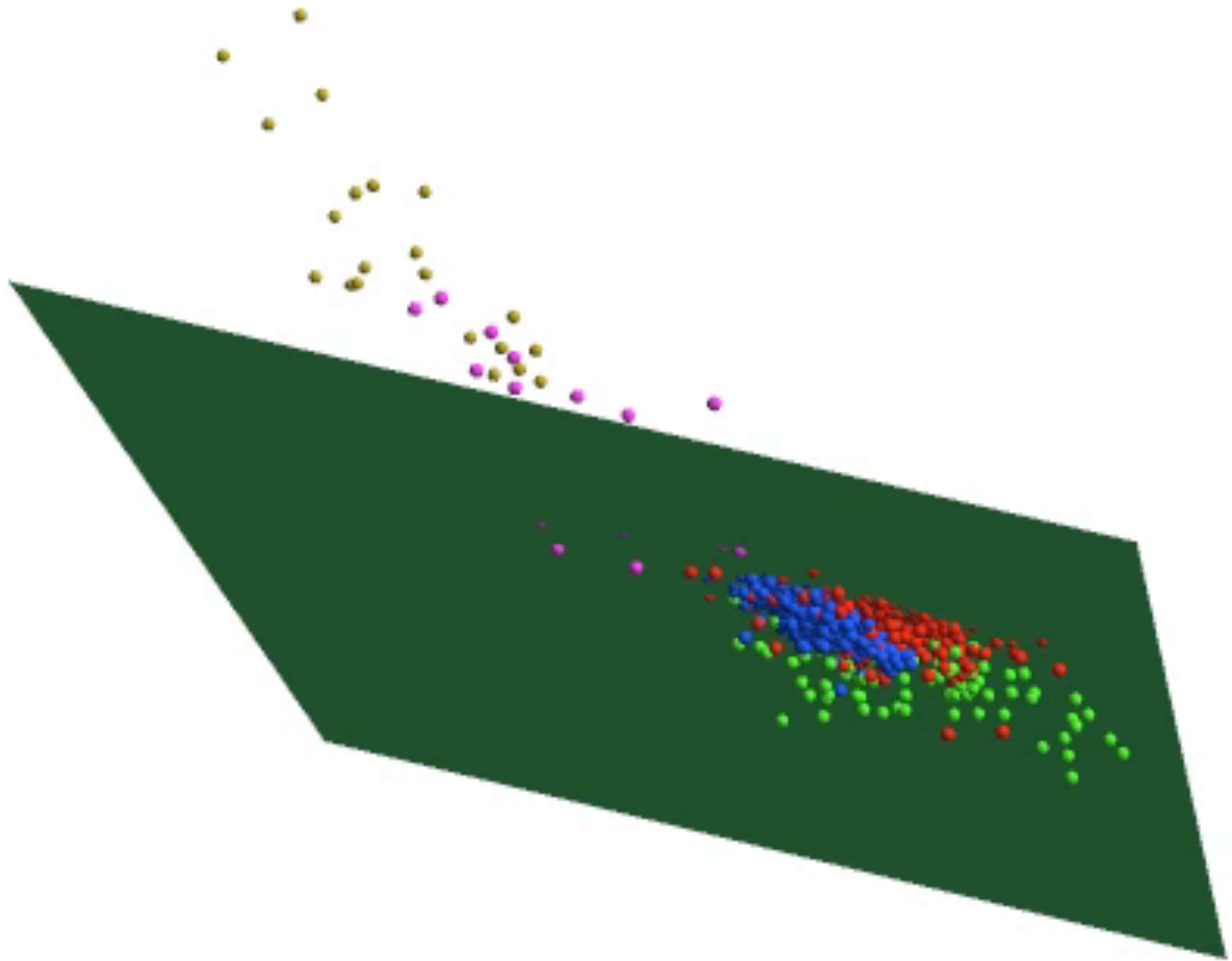
Jorgensen et al. 1996

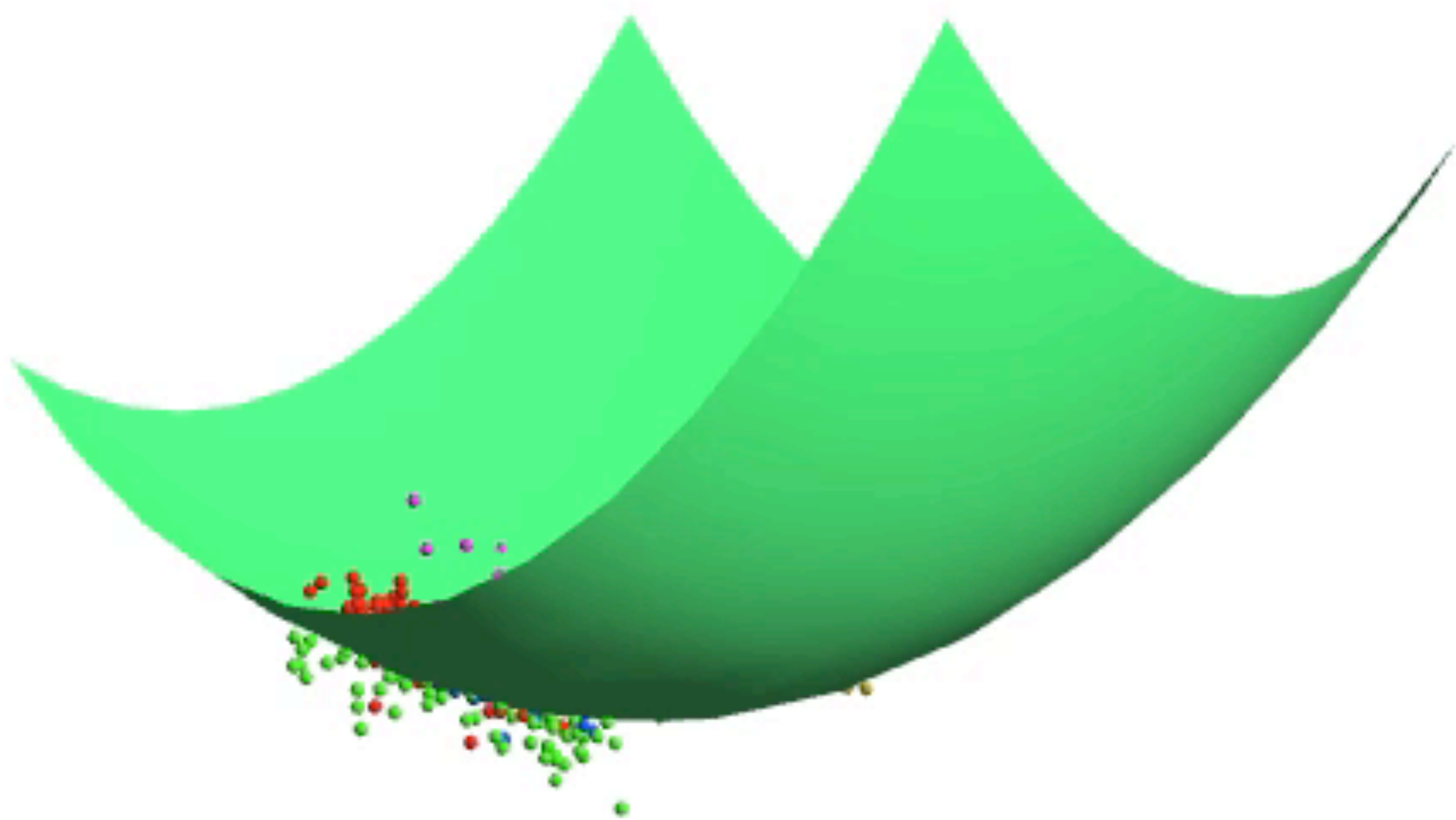


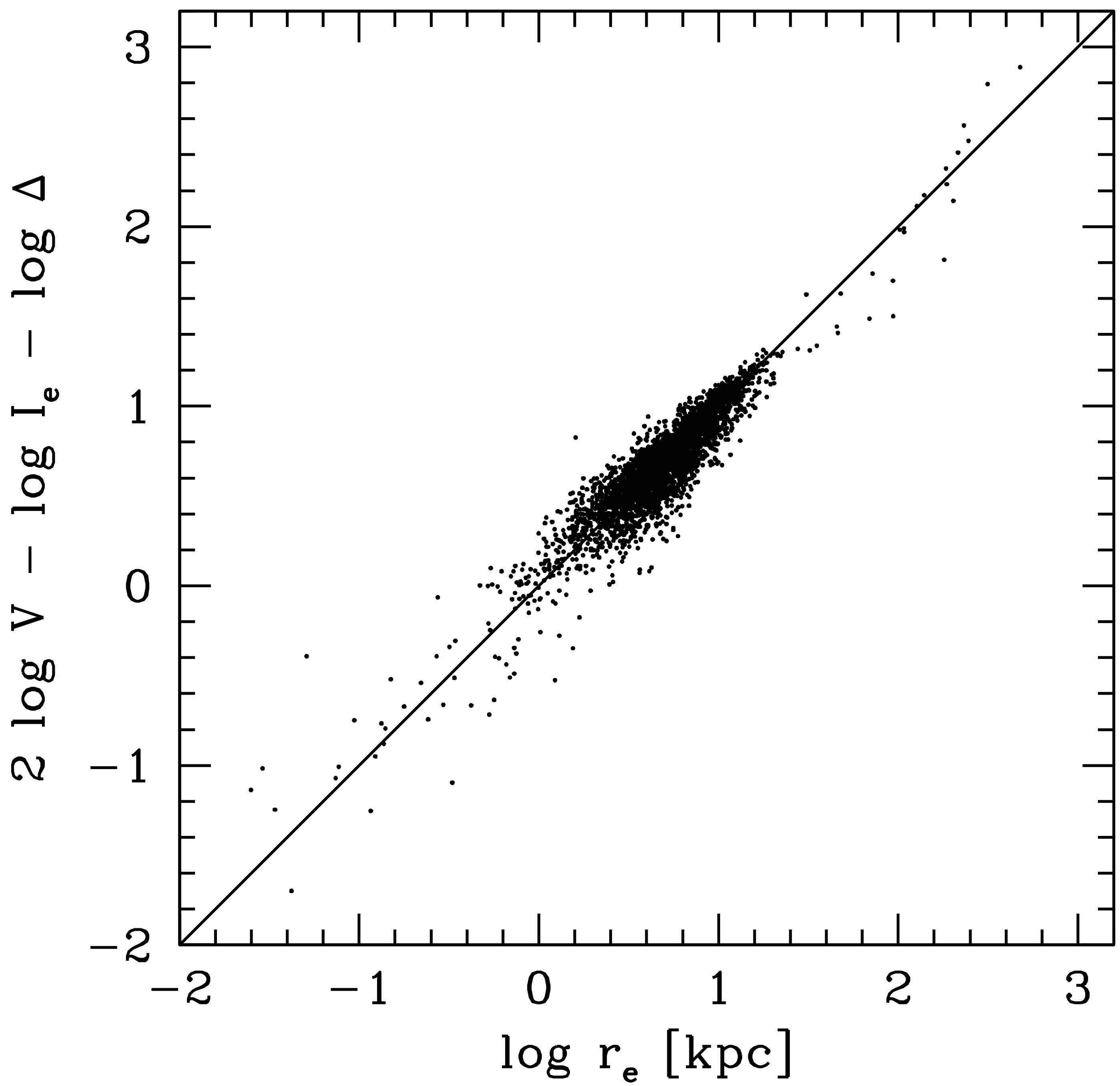
normal ellipticals — Jorgensen et al. 1996

normal spirals — Springob et al. 2007

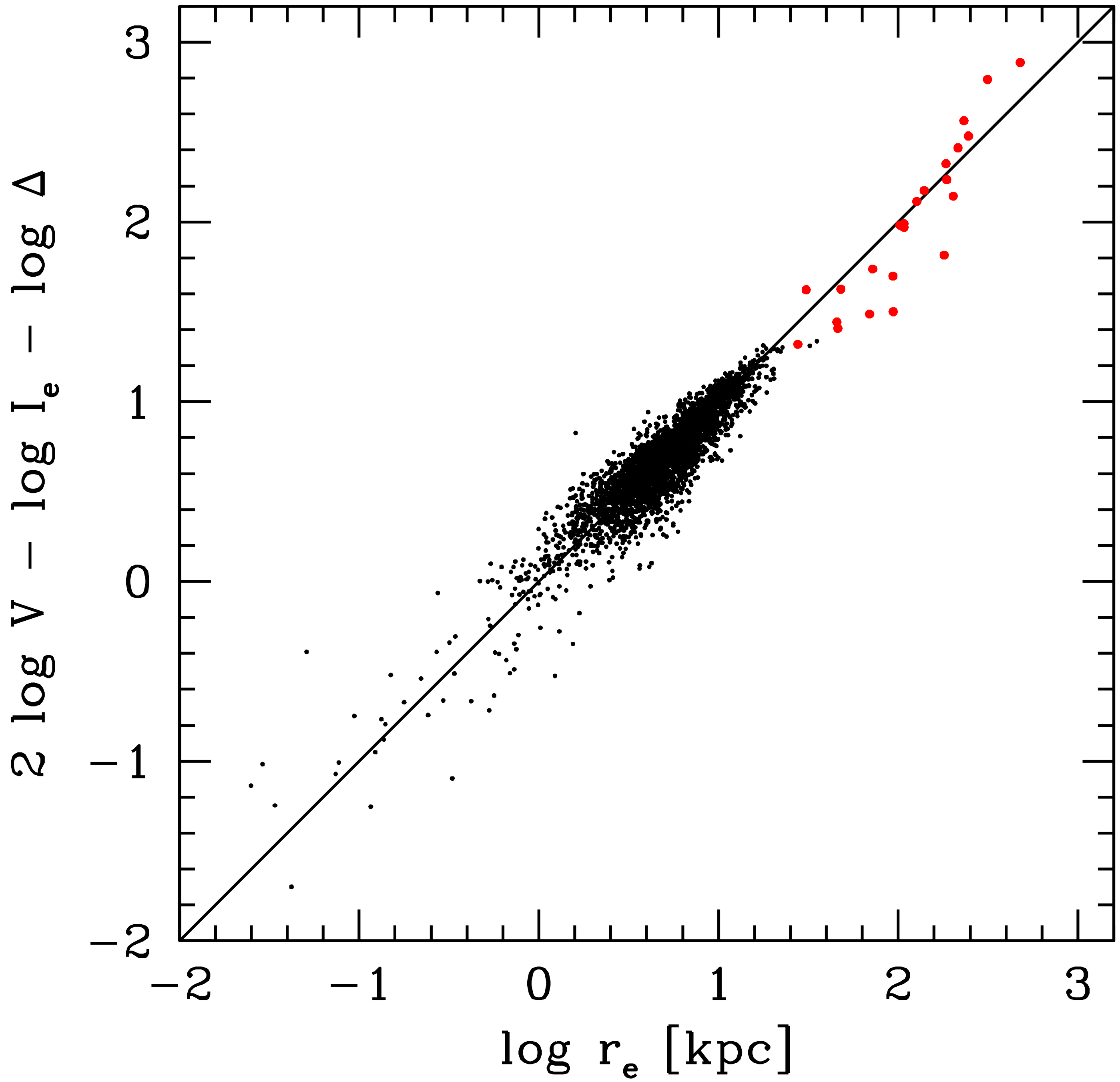
dwarf E's — Geha et al. 2003 & Matkovic and Guzman 2006





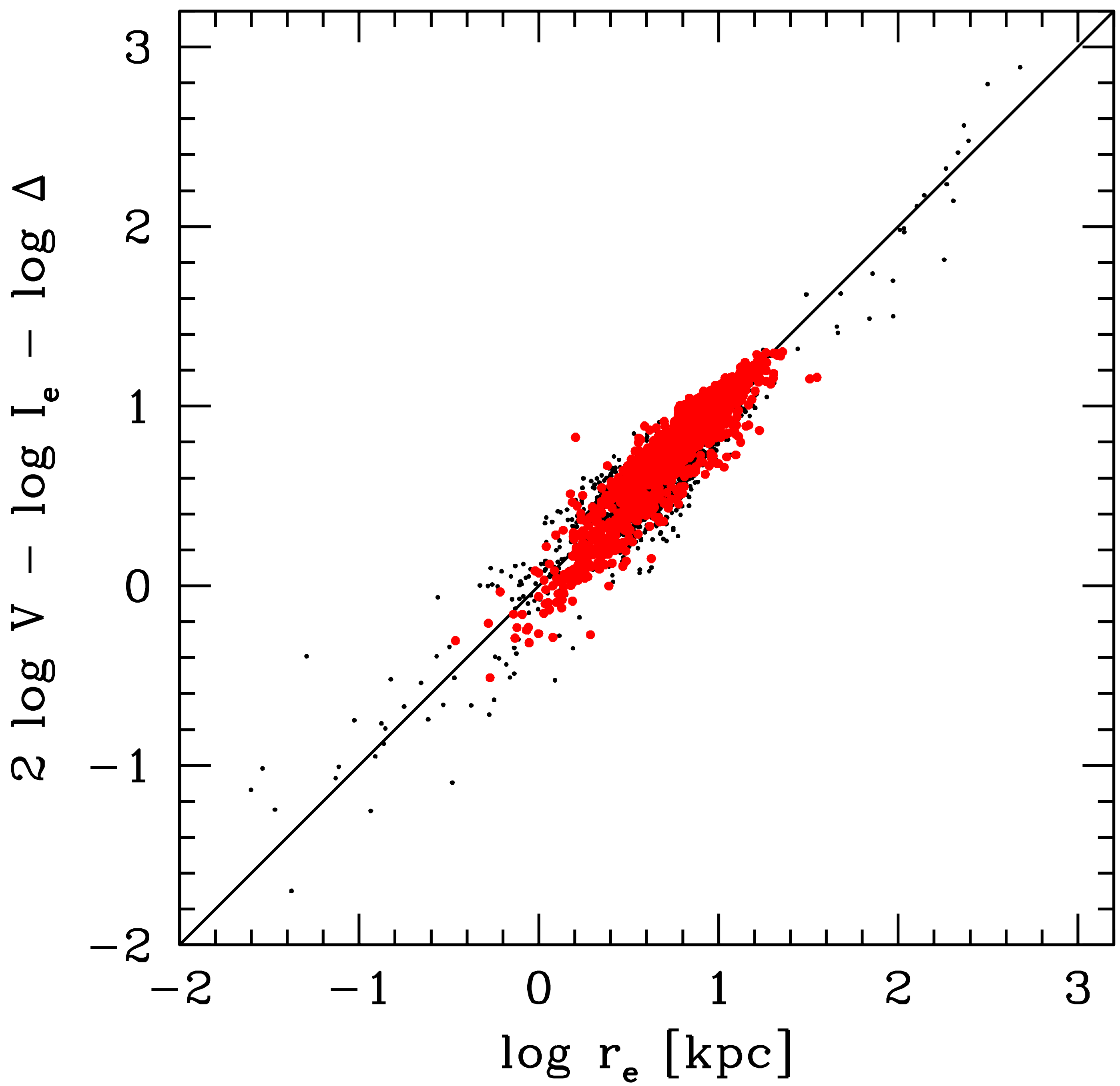


2 log V − log I_e − log Δ
log r_e [kpc]
3
2
1
0
−1
−2
−2
−1
0
1
2
3



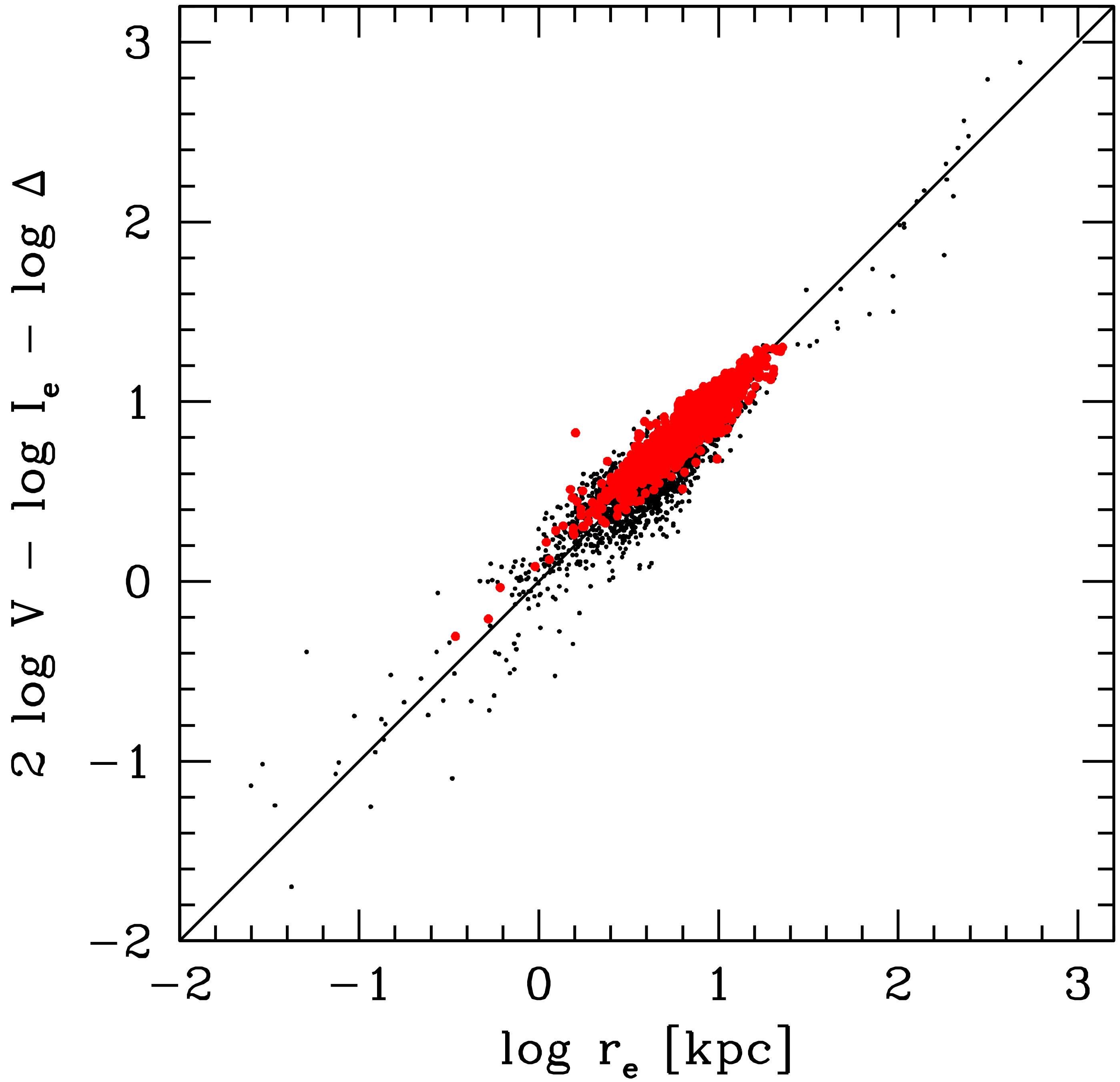
BCGs+ICL

Gonzalez et al. 2005



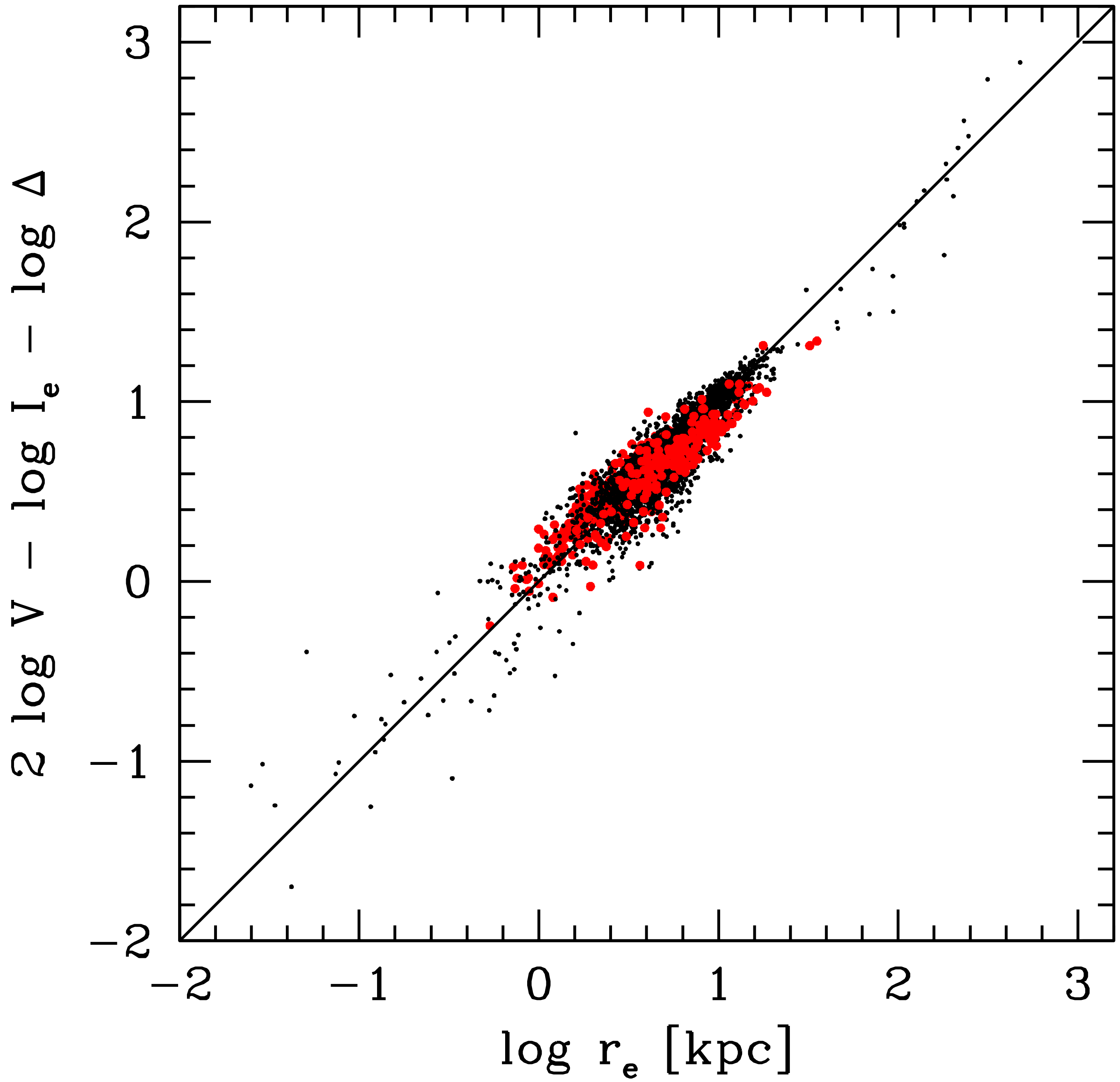
normal ellipticals

Jorgensen et al. 1996



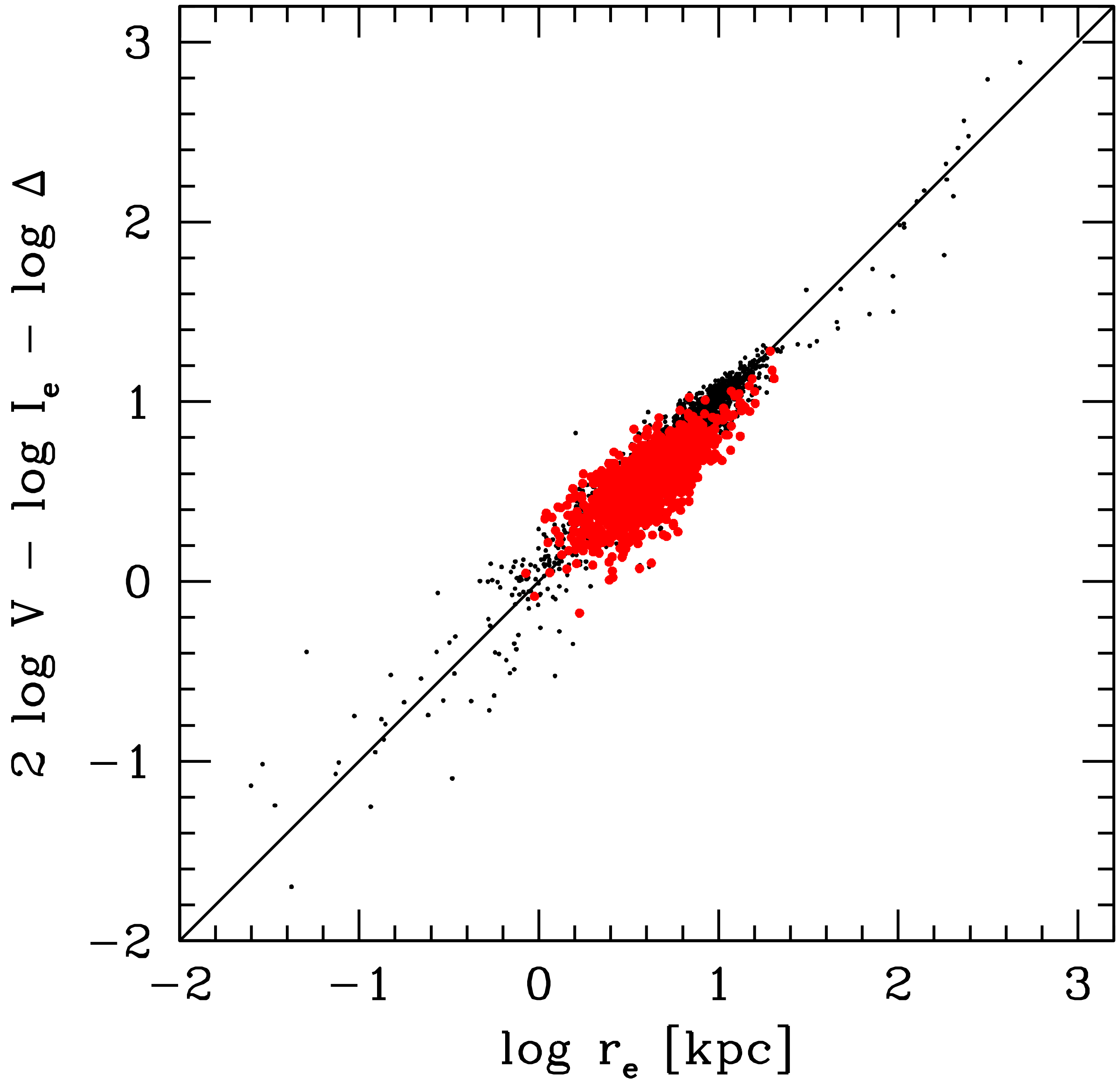
normal disks

Springob et al. 2007



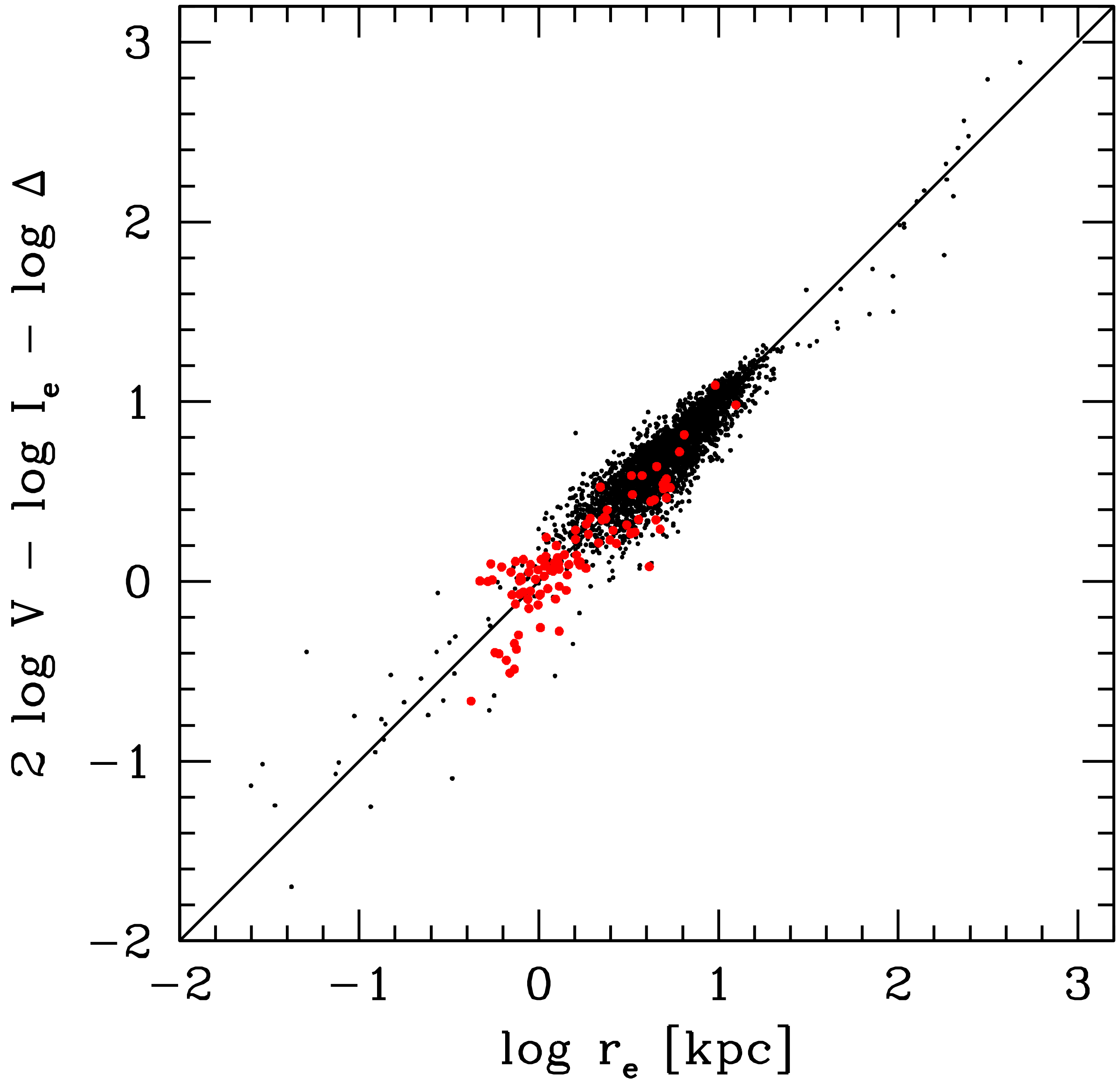
normal disks

Pizagno et al. 2007



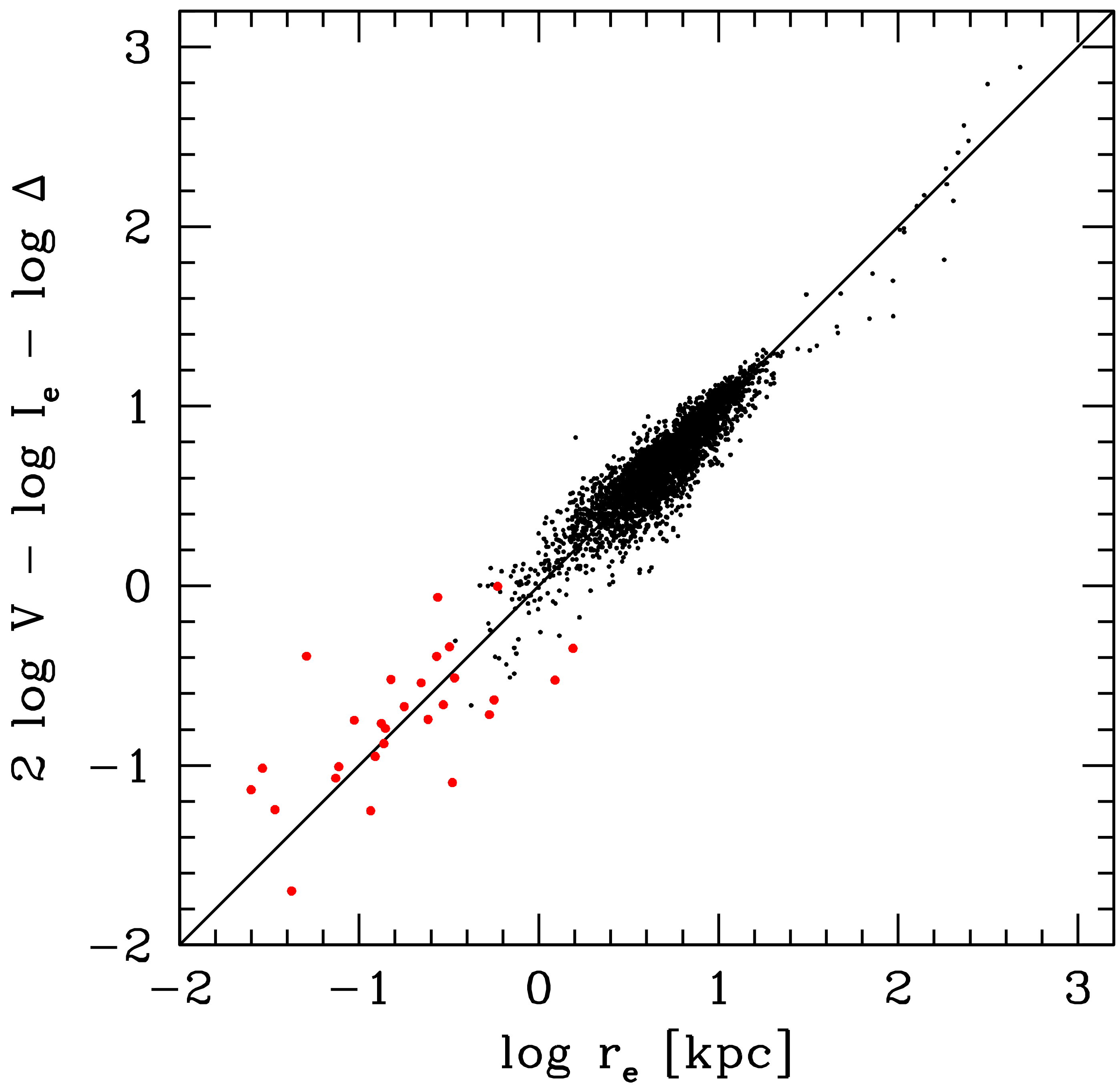
normal disks

Courteau et al. 2007



E's + dwarf E's

Geha et al. 2003 & Matkovic and Guzman 2006



Local Group dwarfs

Walker et al. 2009 (and references therein)

$$\Delta = \log \Upsilon_e - \log A + \log B - C$$

$$\log \Delta \equiv \log \Upsilon_e - \log A + \log B$$

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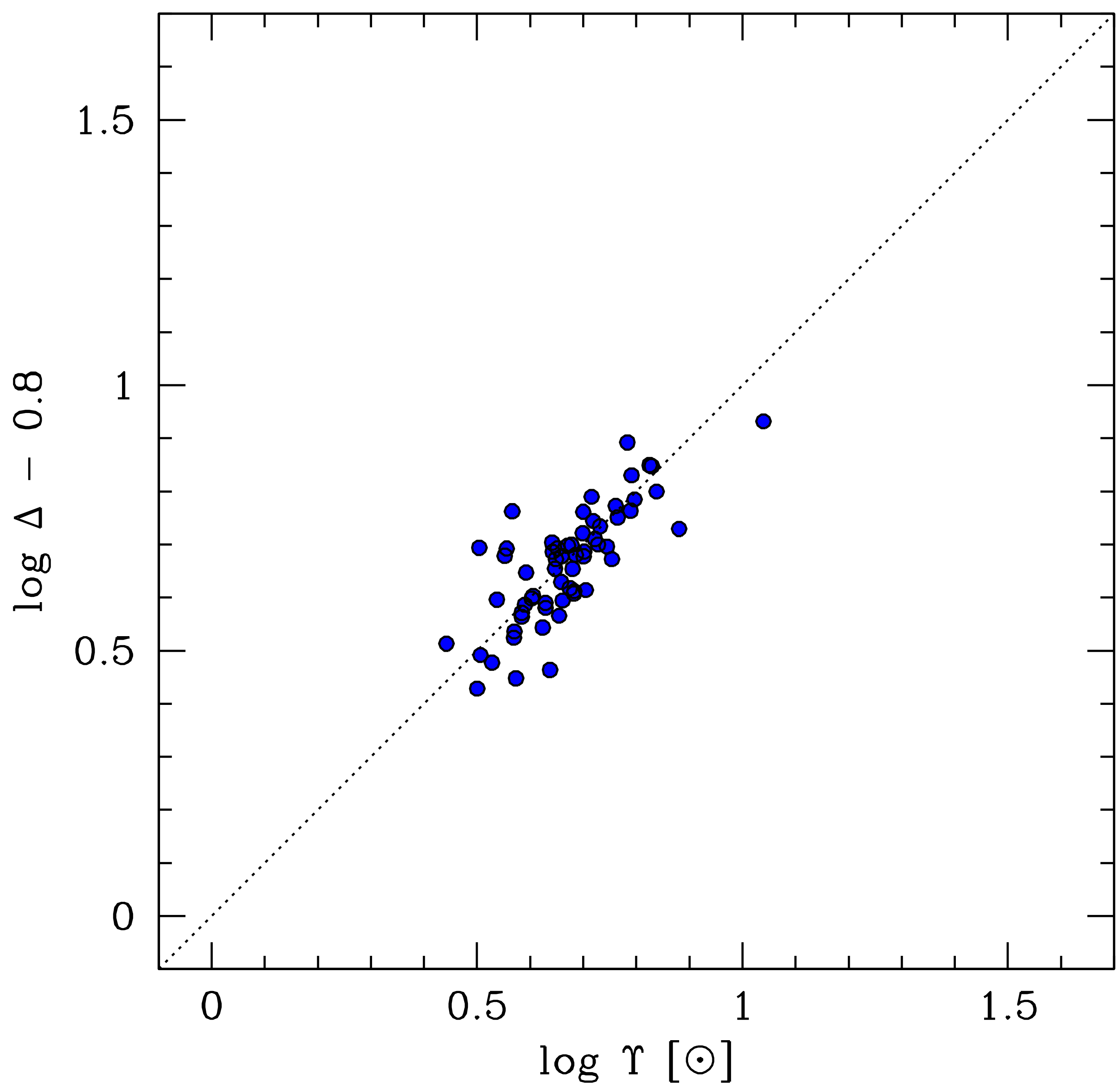

SLACS

Bolton et al. 2008

$$\Delta = \log \Upsilon_e - \log A + \log B - C$$

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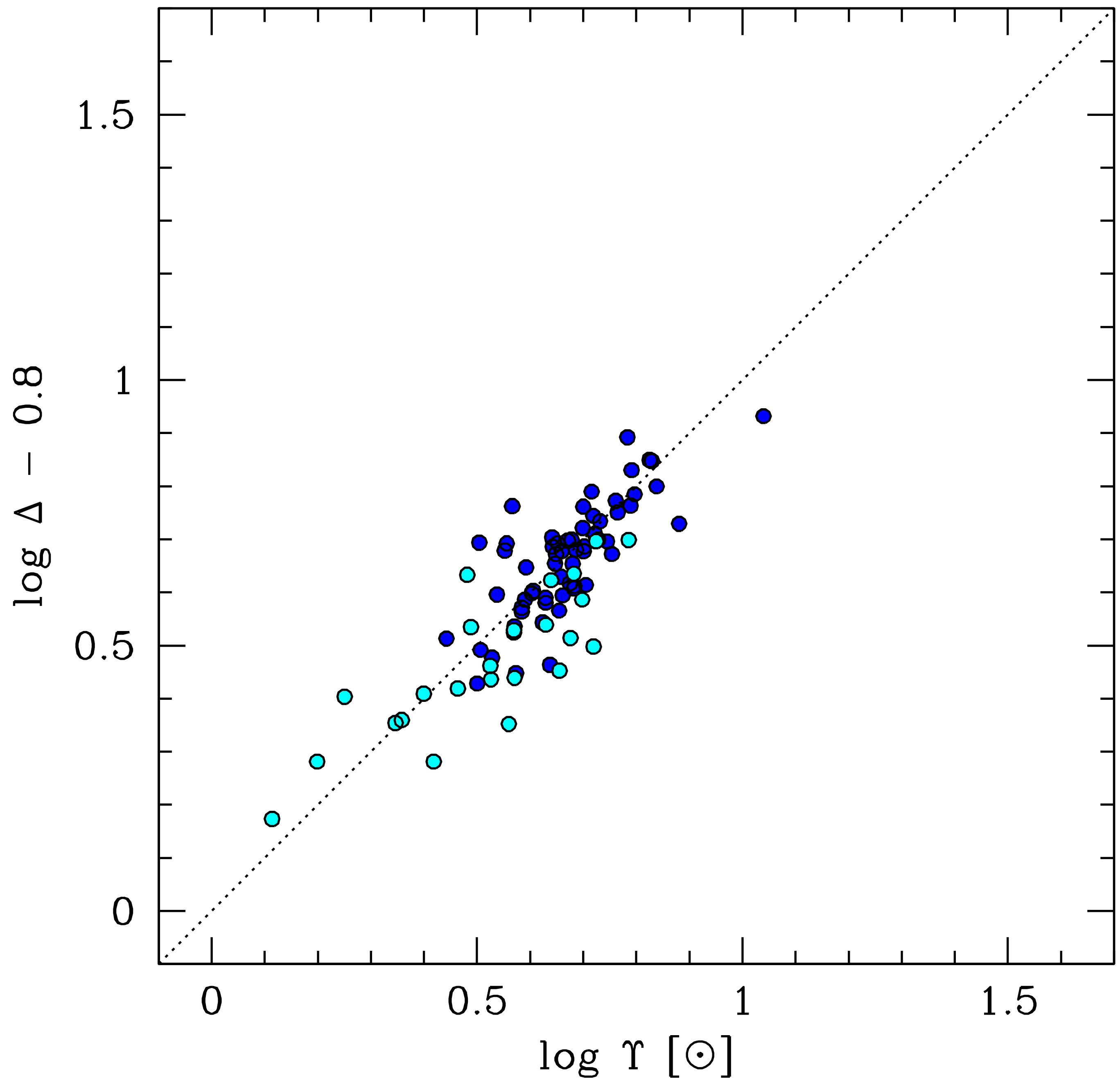
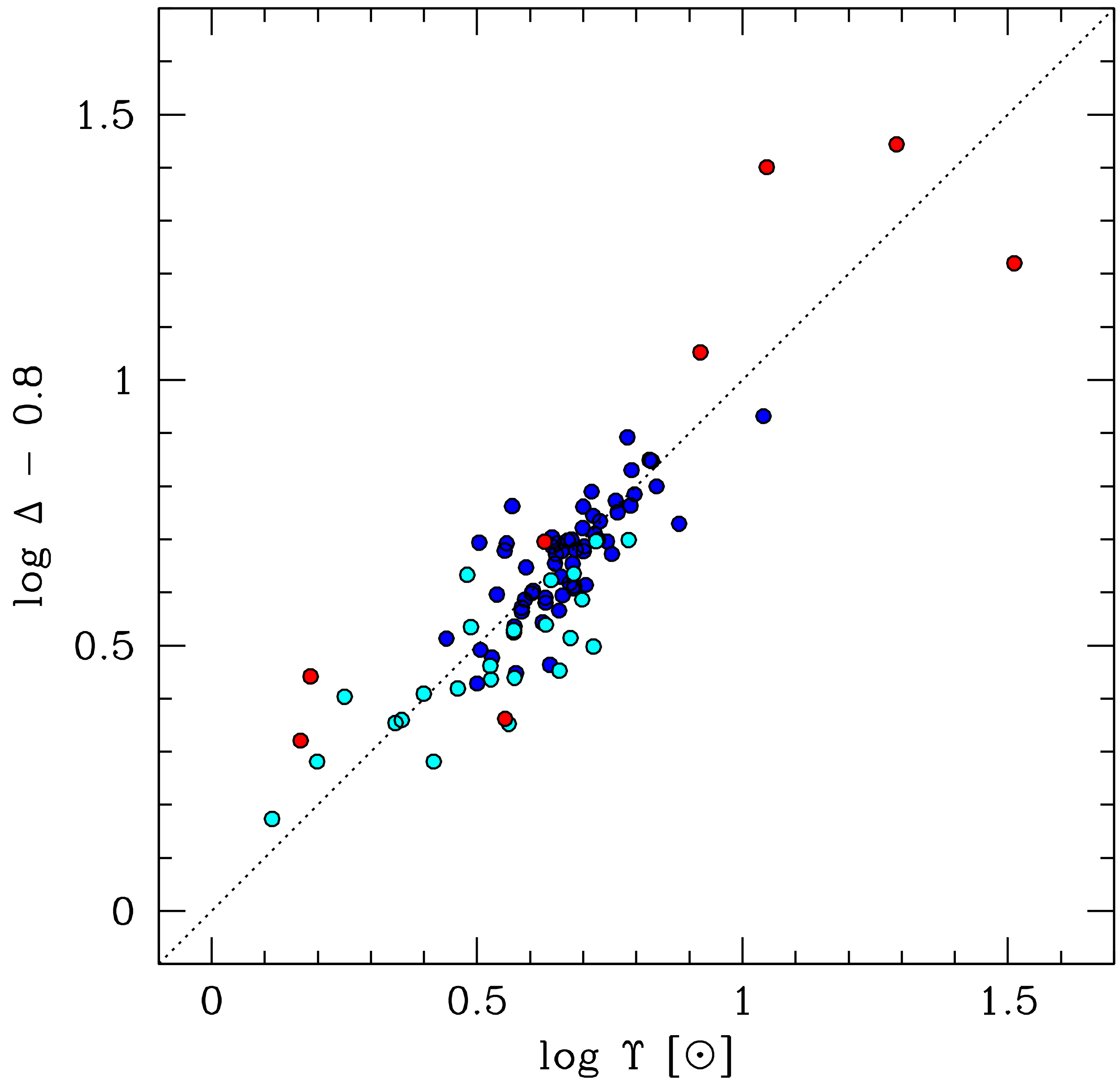


SAURON

Cappellari et al. 2006,2007

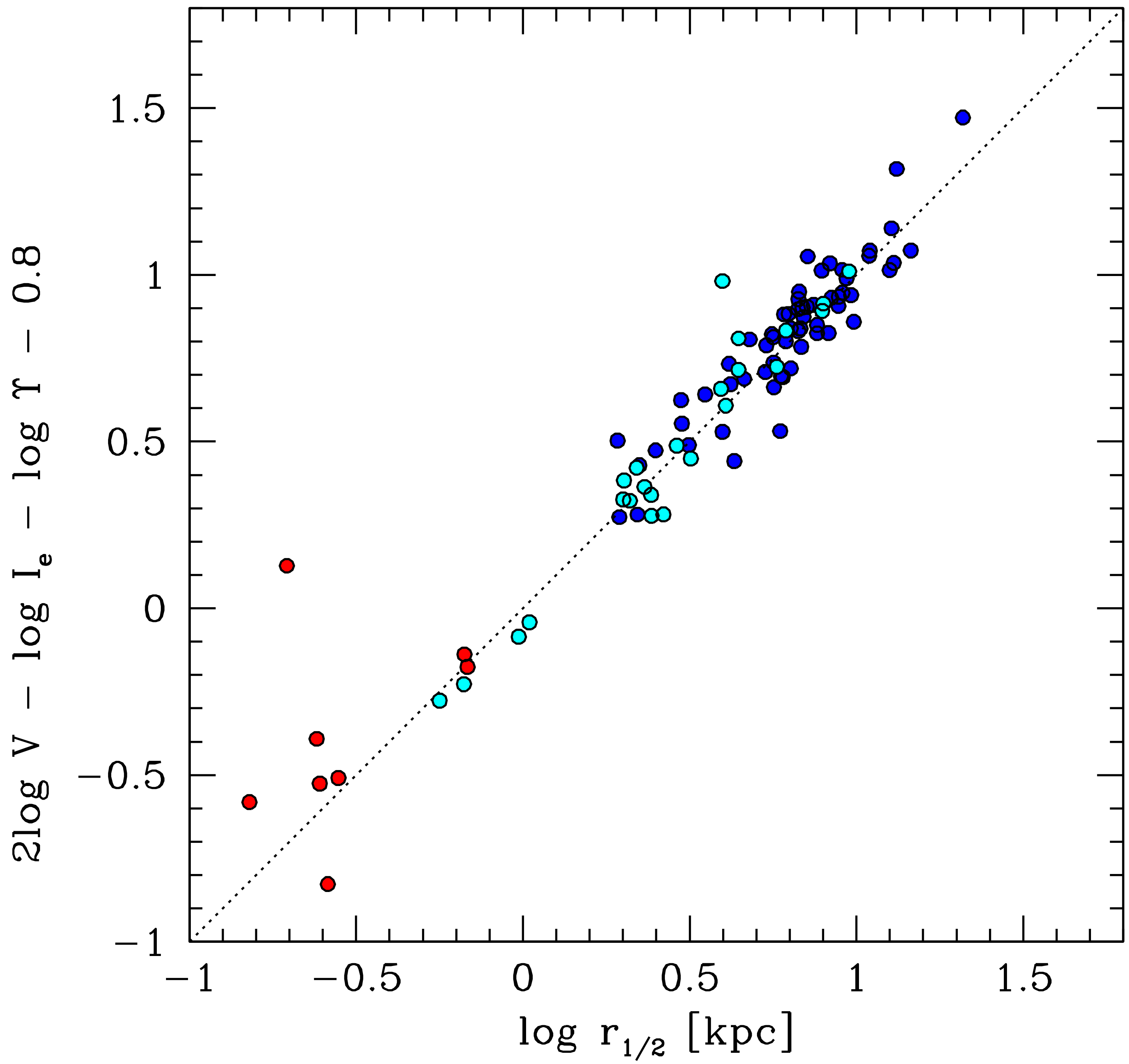
$$\log \Delta \equiv \log \Upsilon_e - \log A + \log B$$



LG dwarfs

Walker et al. 2009

The FM using dynamical M/L's



Testing $V \equiv A(v_{rot}^2/2 + \sigma^2)$

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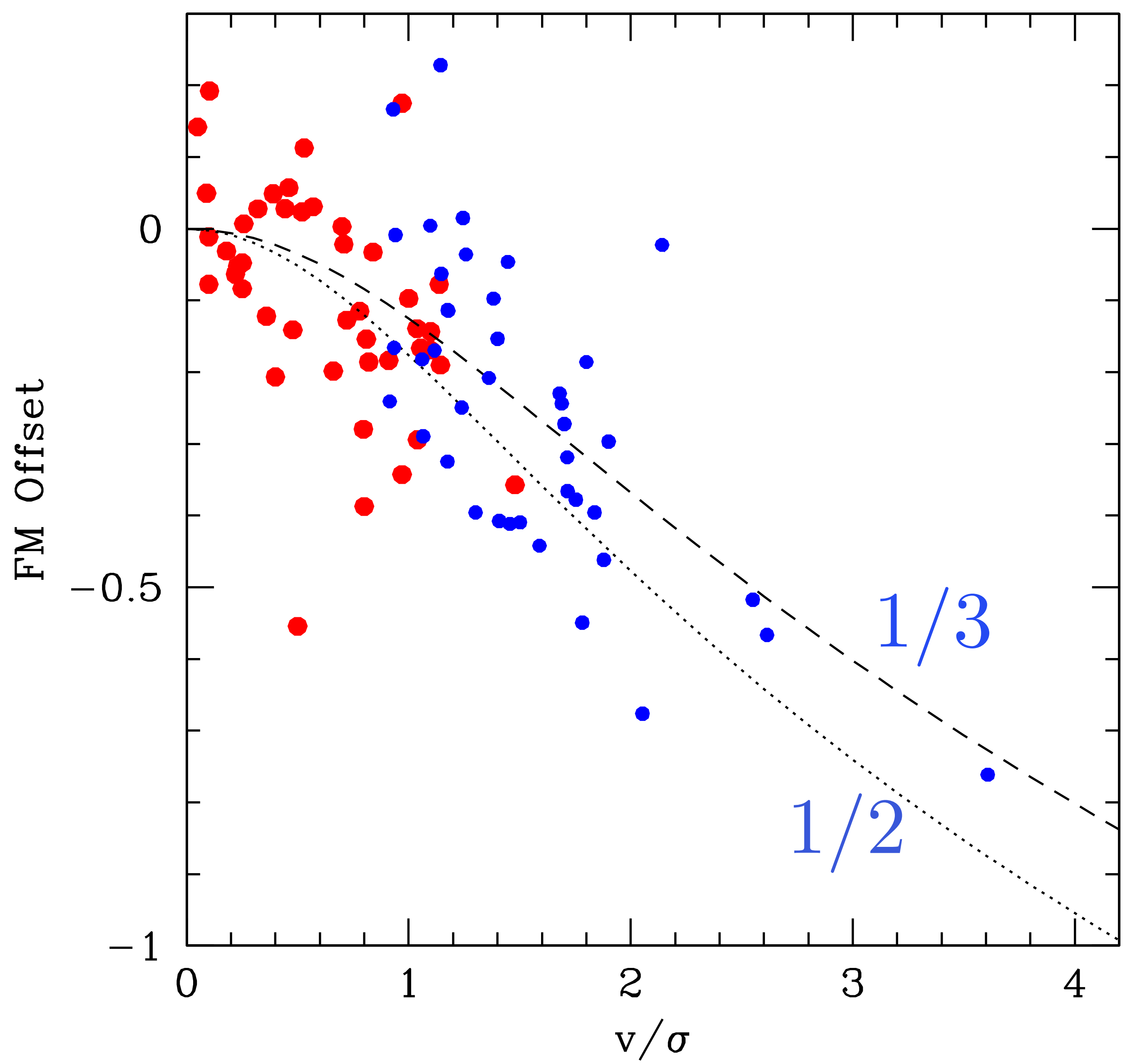
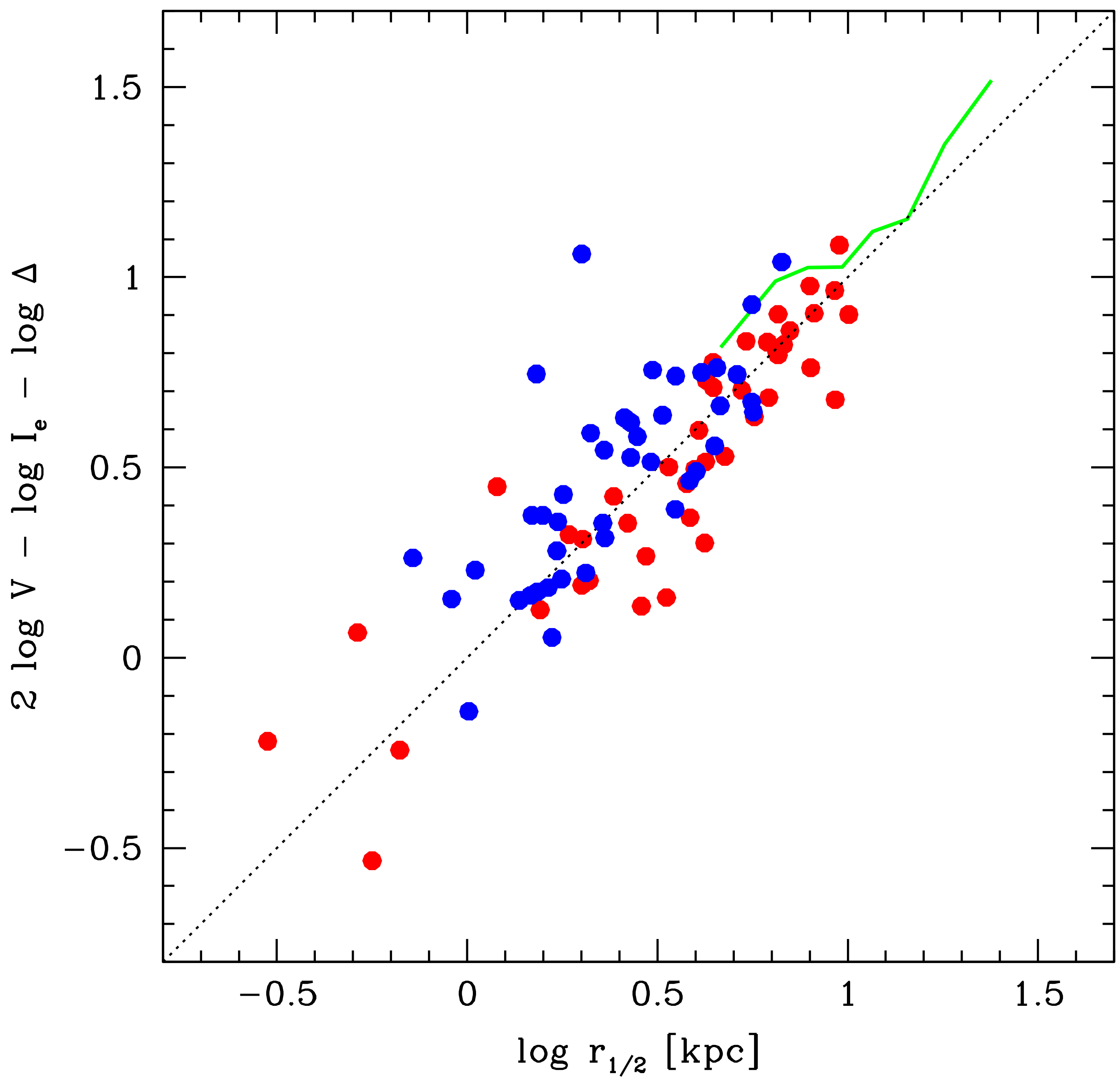


E's from van der Marel & van Dokkum (2007)

S0's from Nordermeer et al. (2008)



E & S0's share FM

the story so far...

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- the combining of v and σ is empirically verified

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- $\Delta = f(V, I_e)$ (but not simple power laws)

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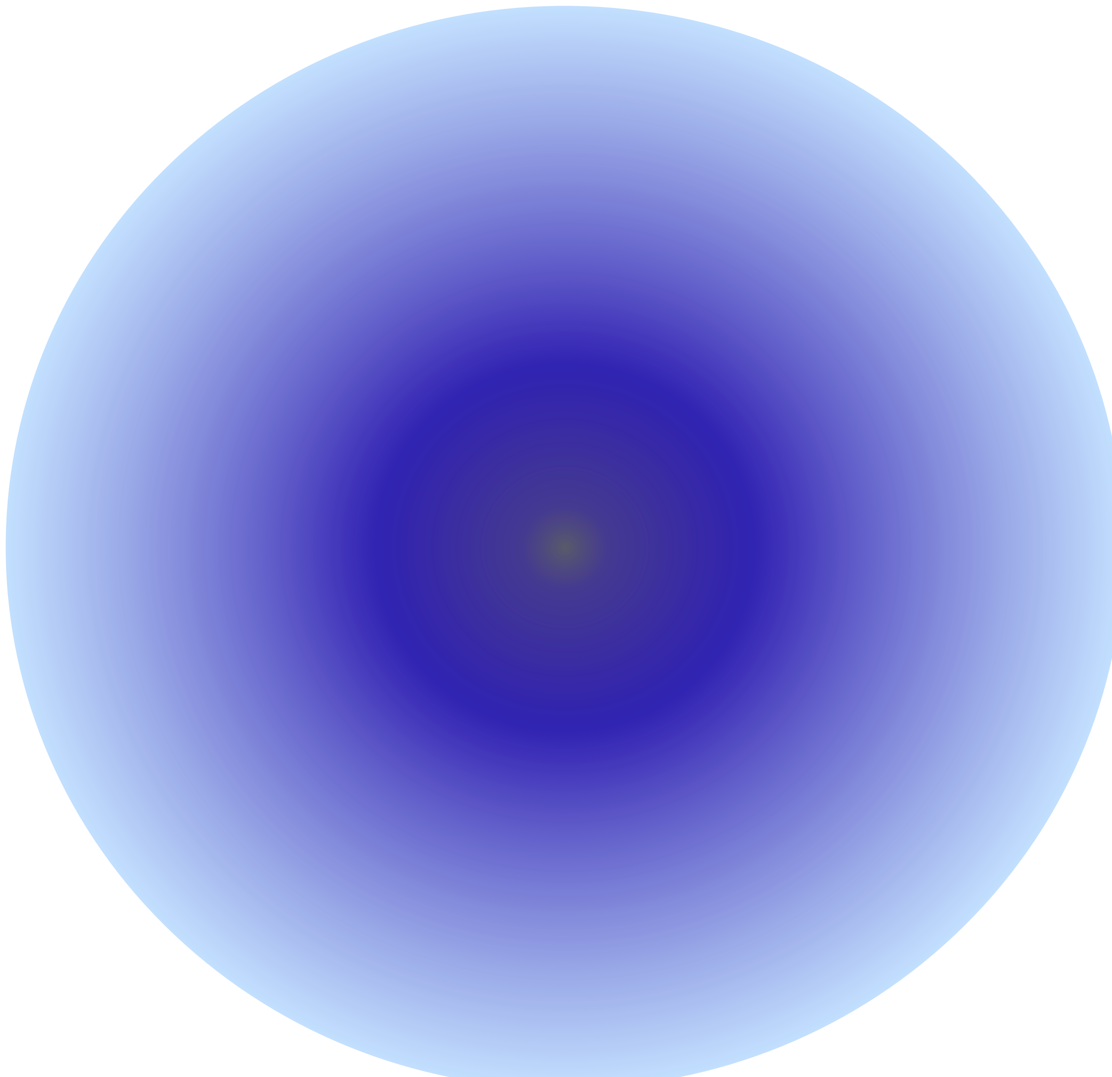
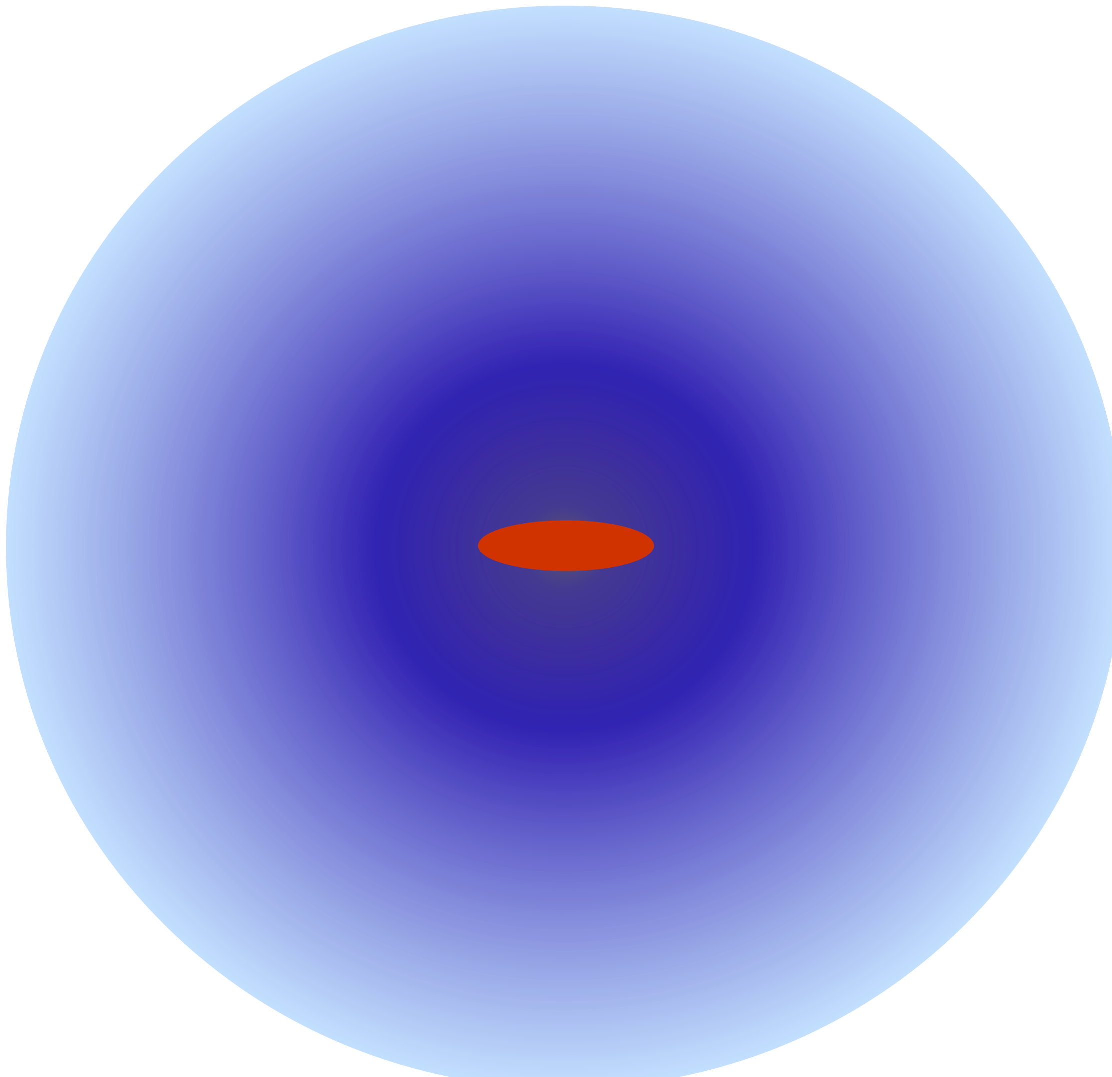
the story so far...

- the combining of v and σ is empirically verified
- $\Delta = f(V, I_e)$ (but not simple power laws)
- galaxies of all types & luminosities fall on 2-D surface in 3-D parameter space (unification of TF, FP, +)
- two parameters drive global galactic structure (primarily through M/L)

DM (NFW) + baryons

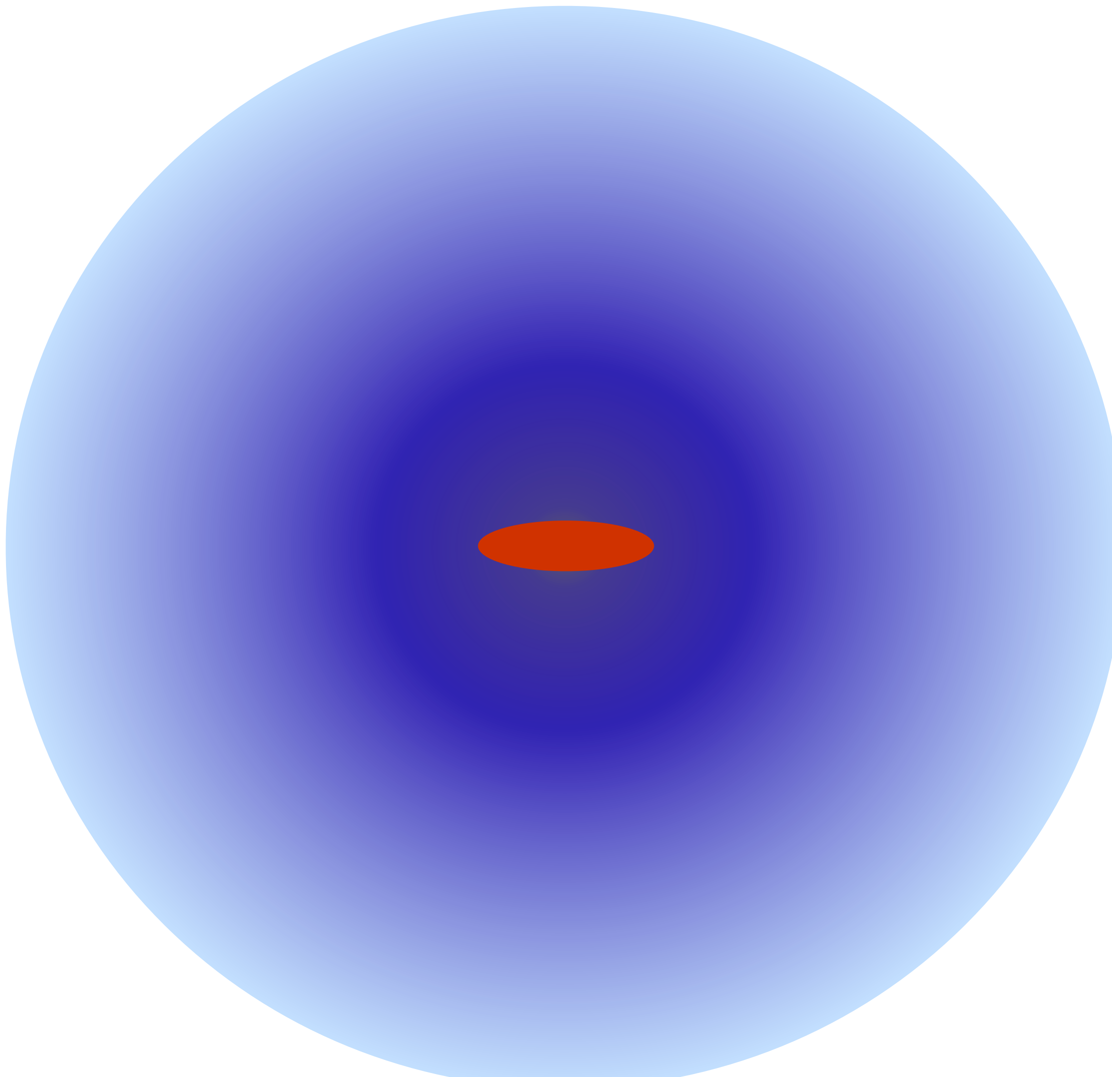


characterized by M and J/M



DM (NFW) + baryons

baryons dissipate E
but conserve J



DM (NFW) + baryons

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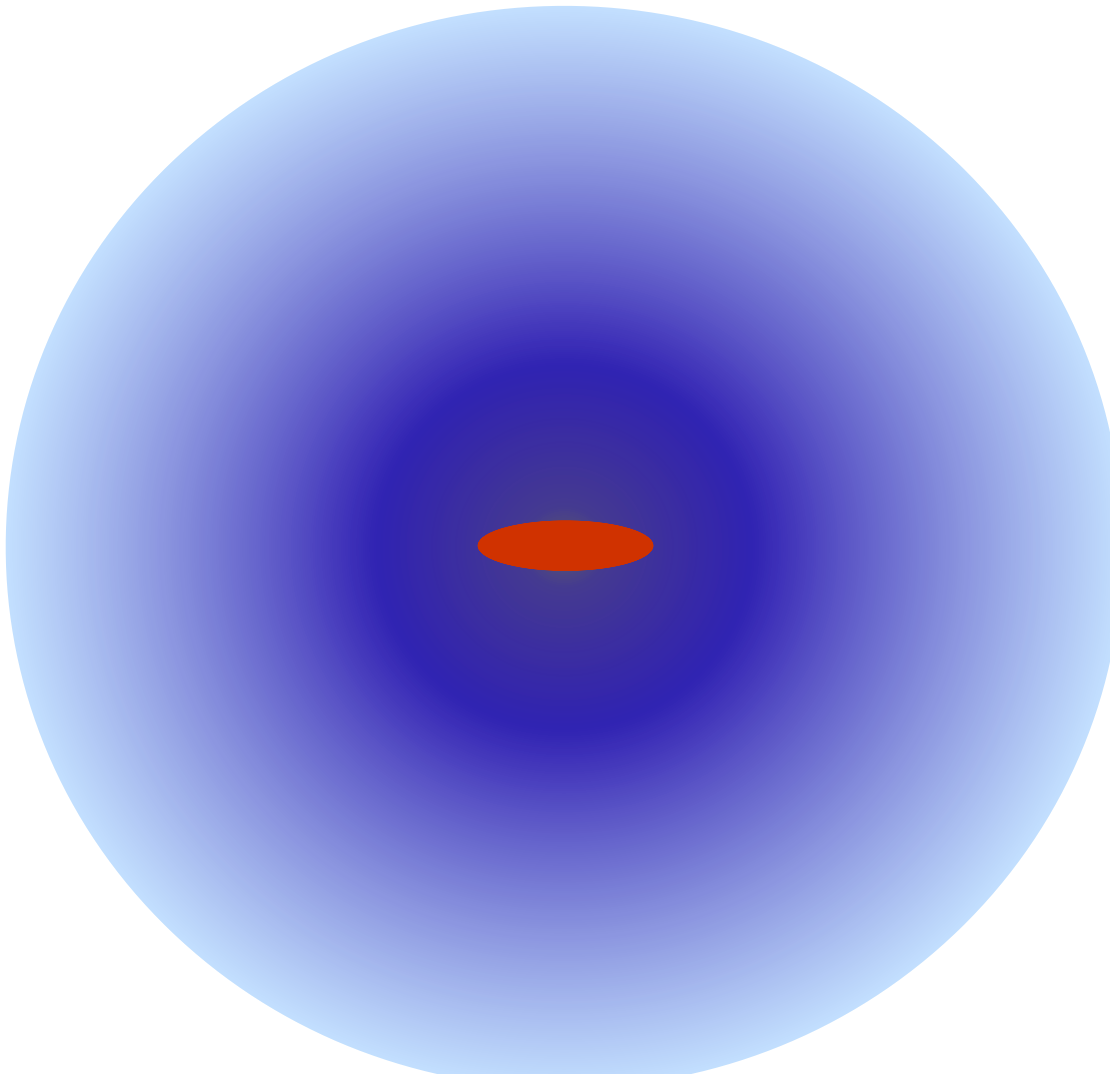
observed radial profiles



DM (NFW) + baryons

baryons dissipate E
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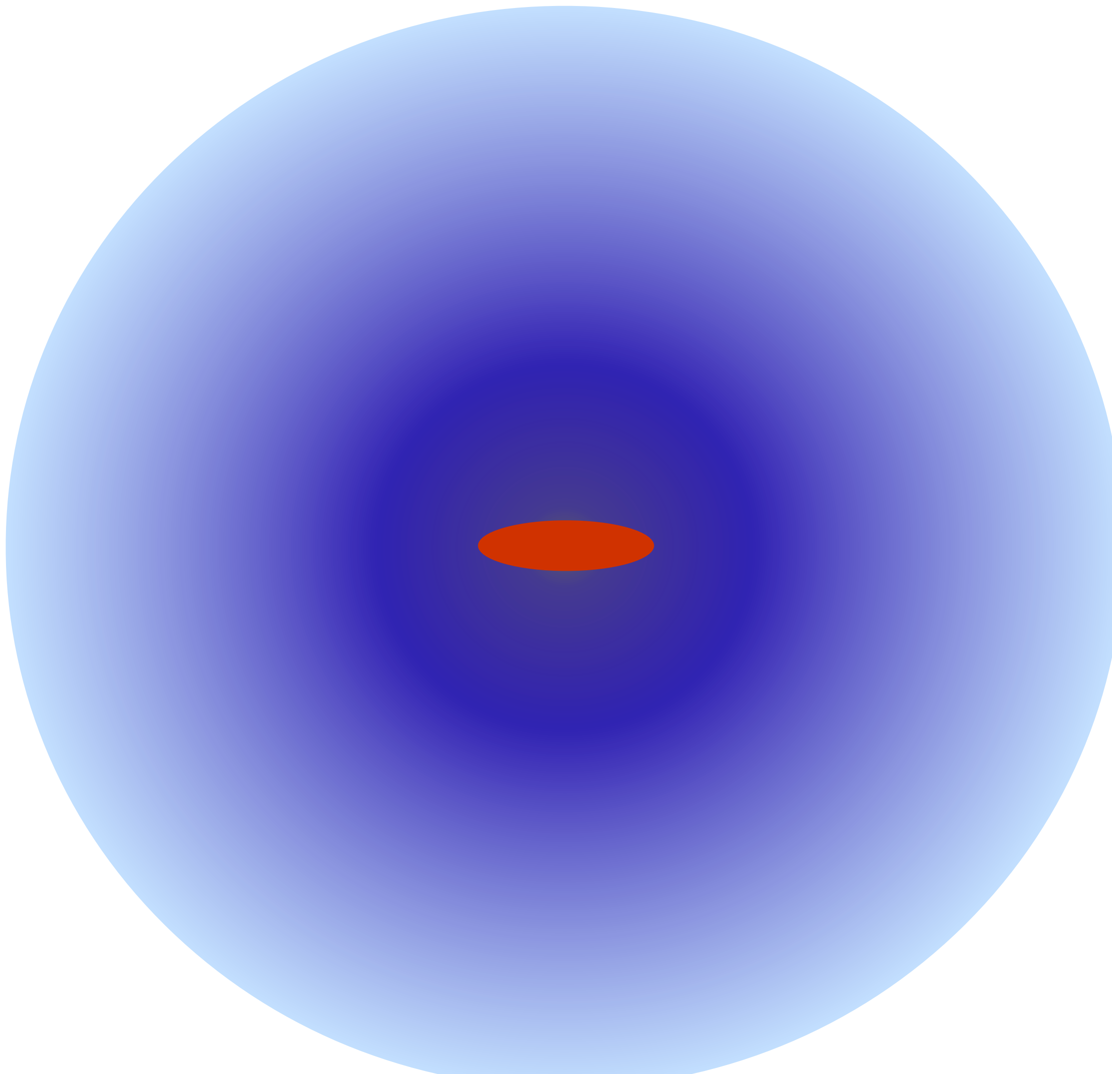
long & illustrious history, cf. Crampin & Hoyle 1964; Freeman 1970; Fall & Efstathiou 1980; Fall 1983; Blumenthal et al. 1984,1986; Flores et al. 1993 Dalcanton et al. 1997; Mo, Mao & White 1998,1999



DM (NFW) + baryons

baryons dissipate E
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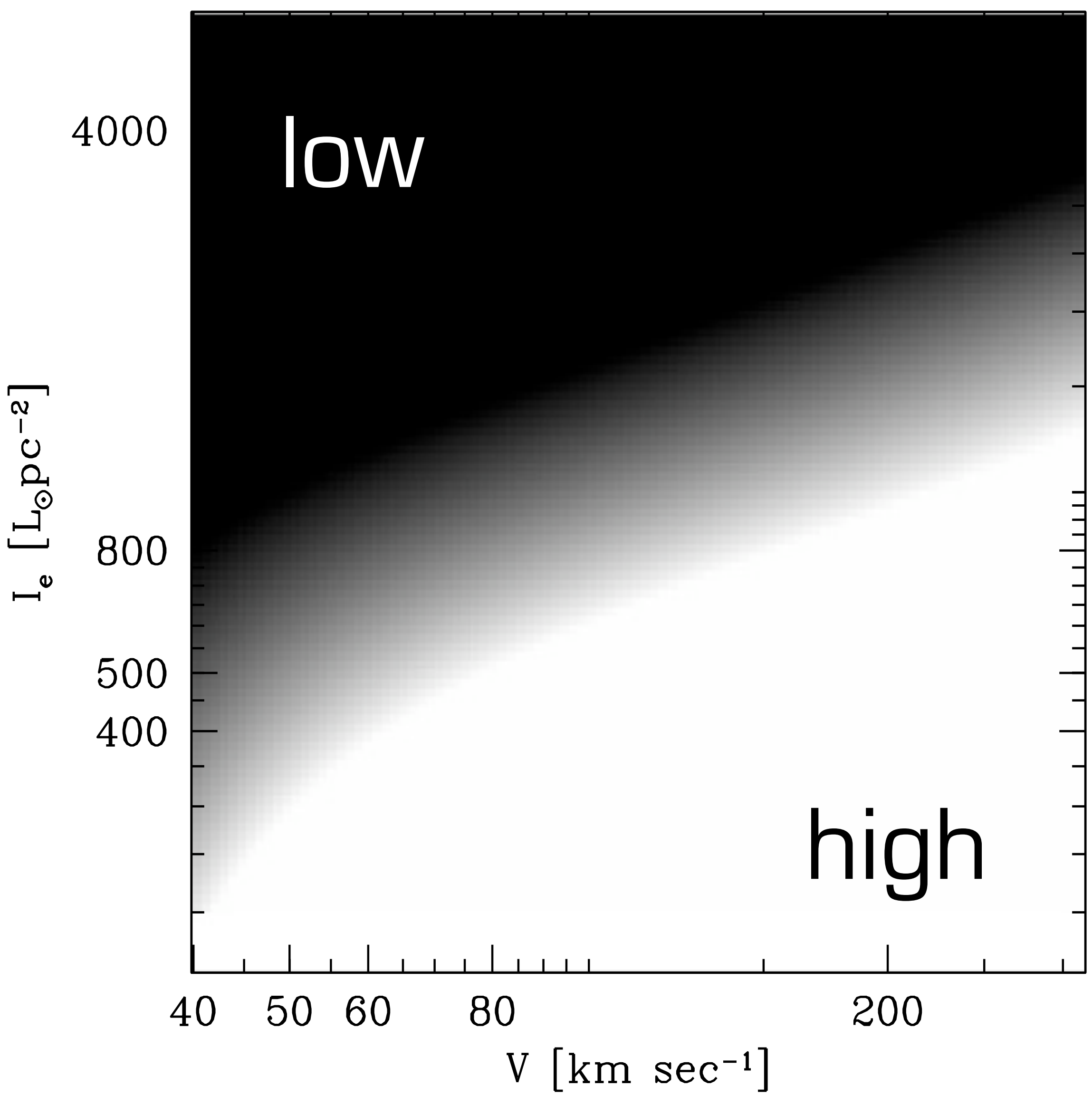
and settle into
observed radial profiles

adiabatically compress DM
(quantities calculating using CONTRA; Gnedin et al. 2004)

spin parameter

for spheroids



spin parameter

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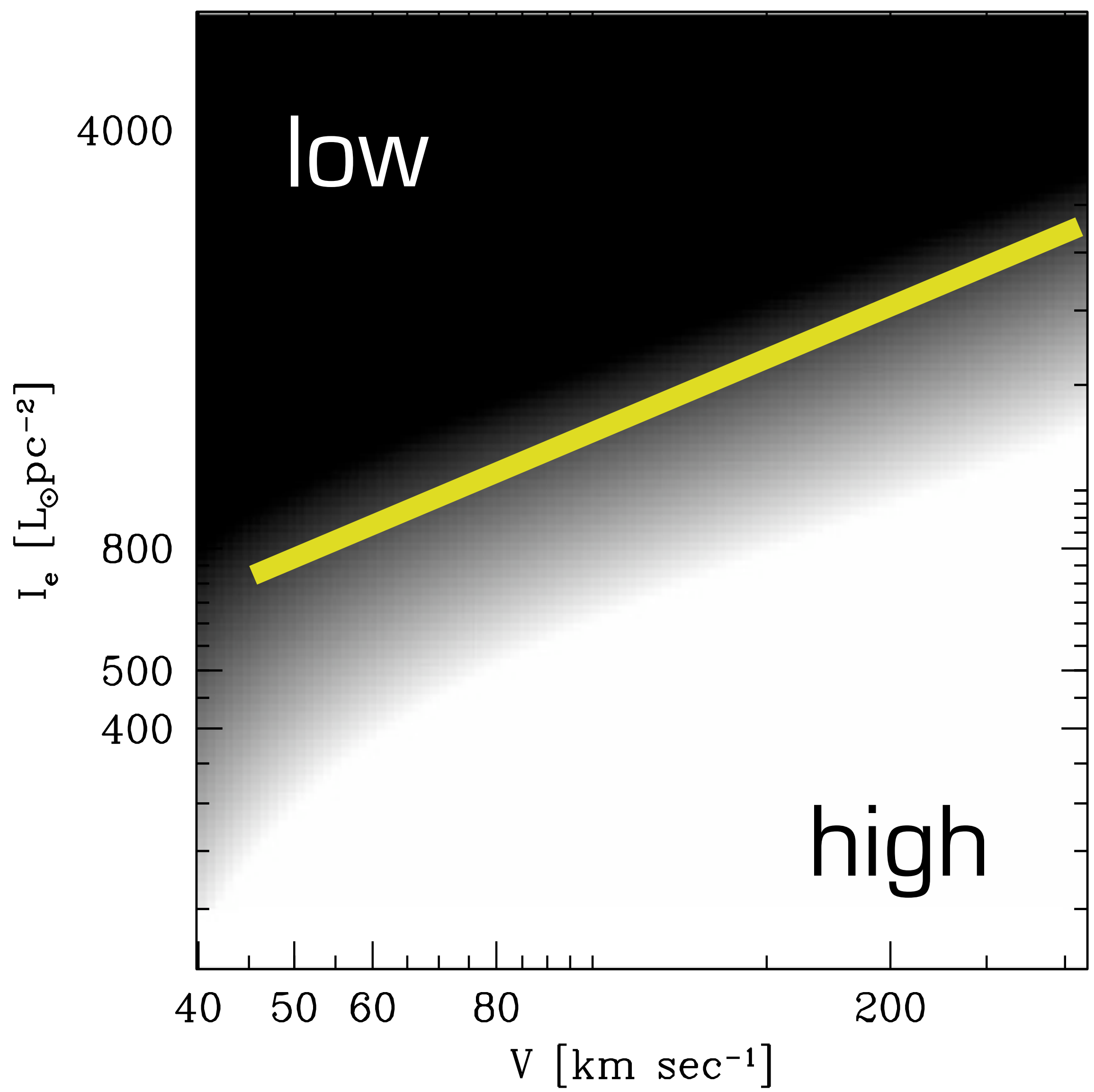
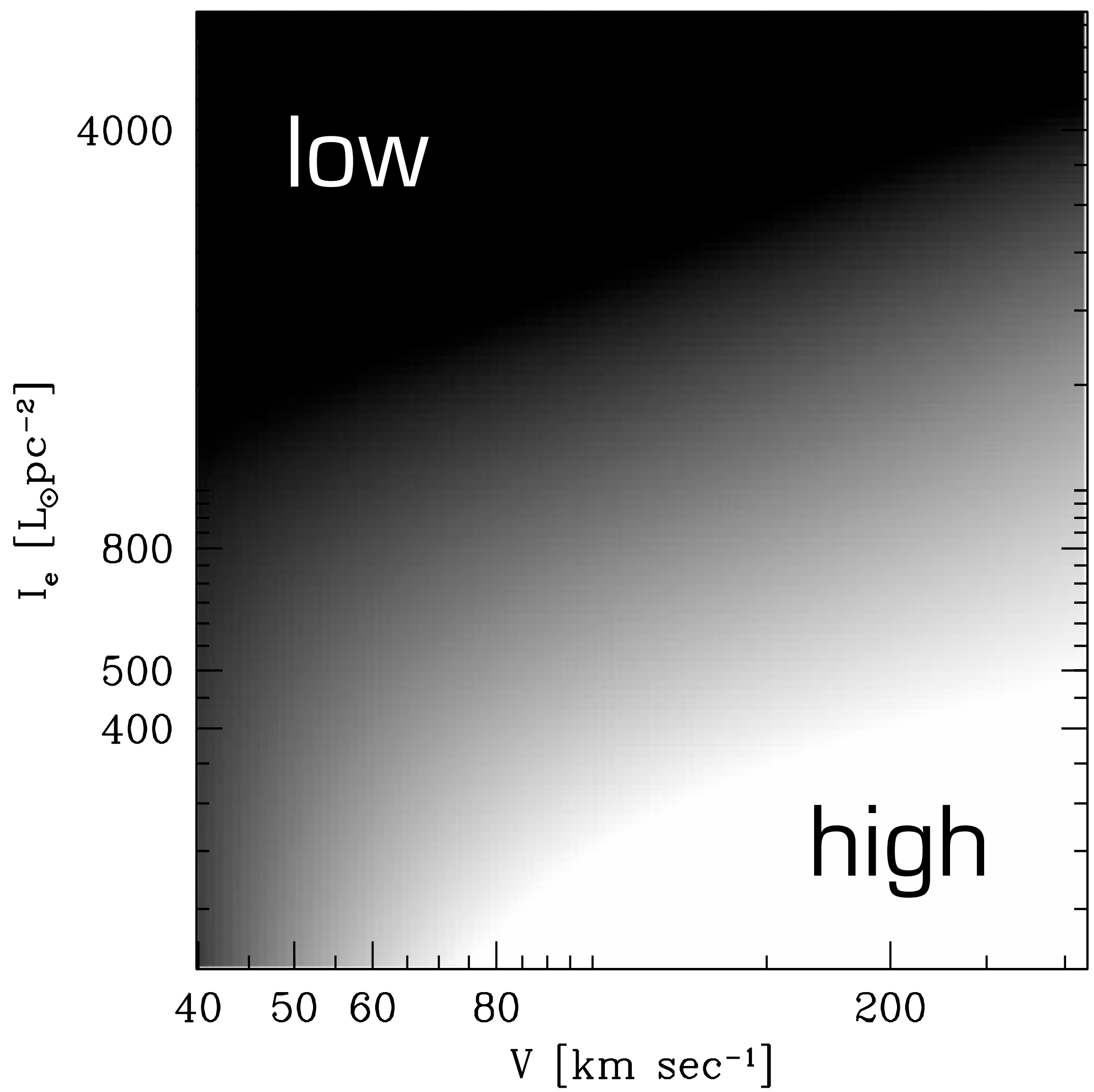


$\lambda = 0.035$

Bullock et al. 2001

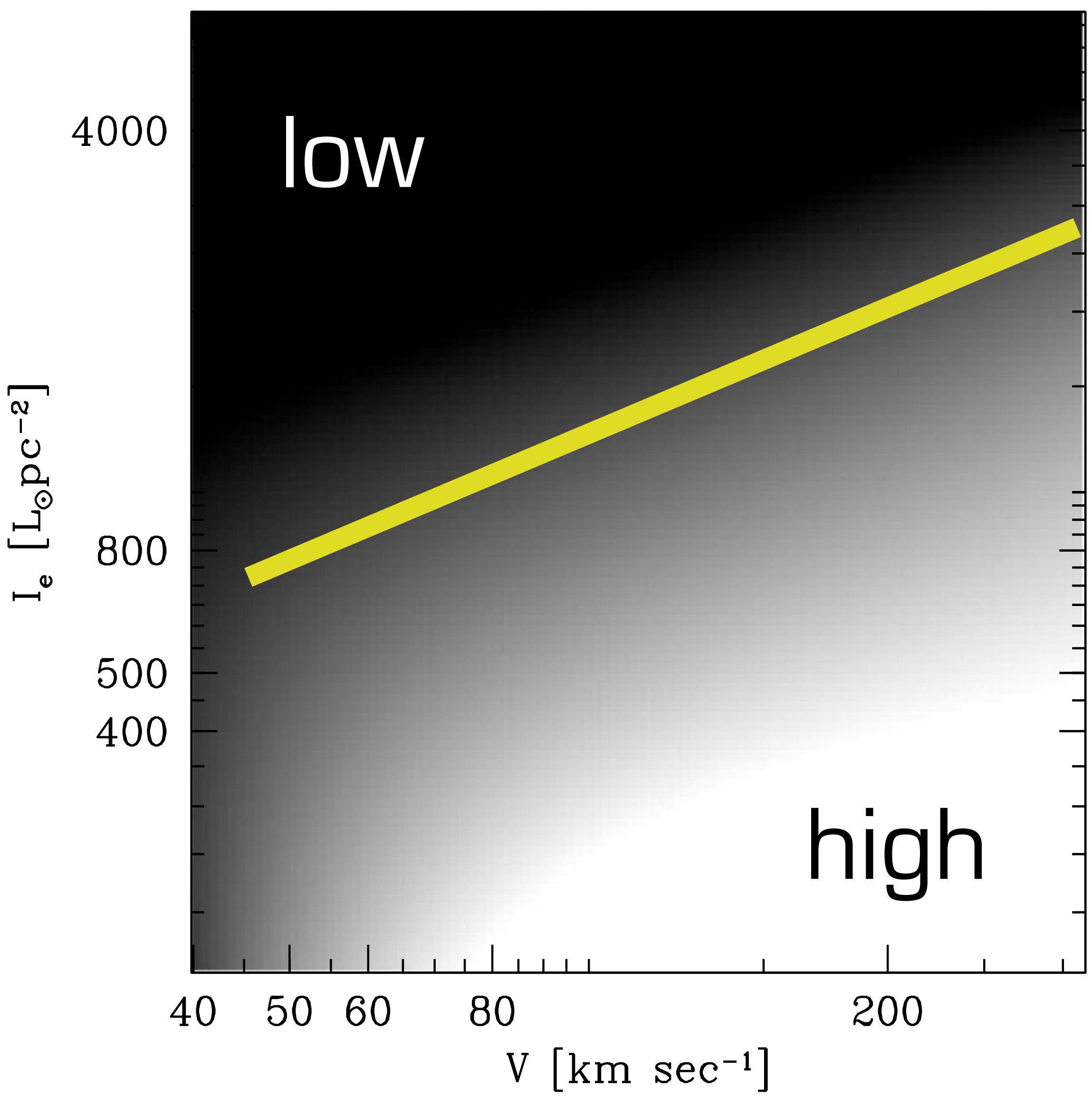
efficiency

for spheroids



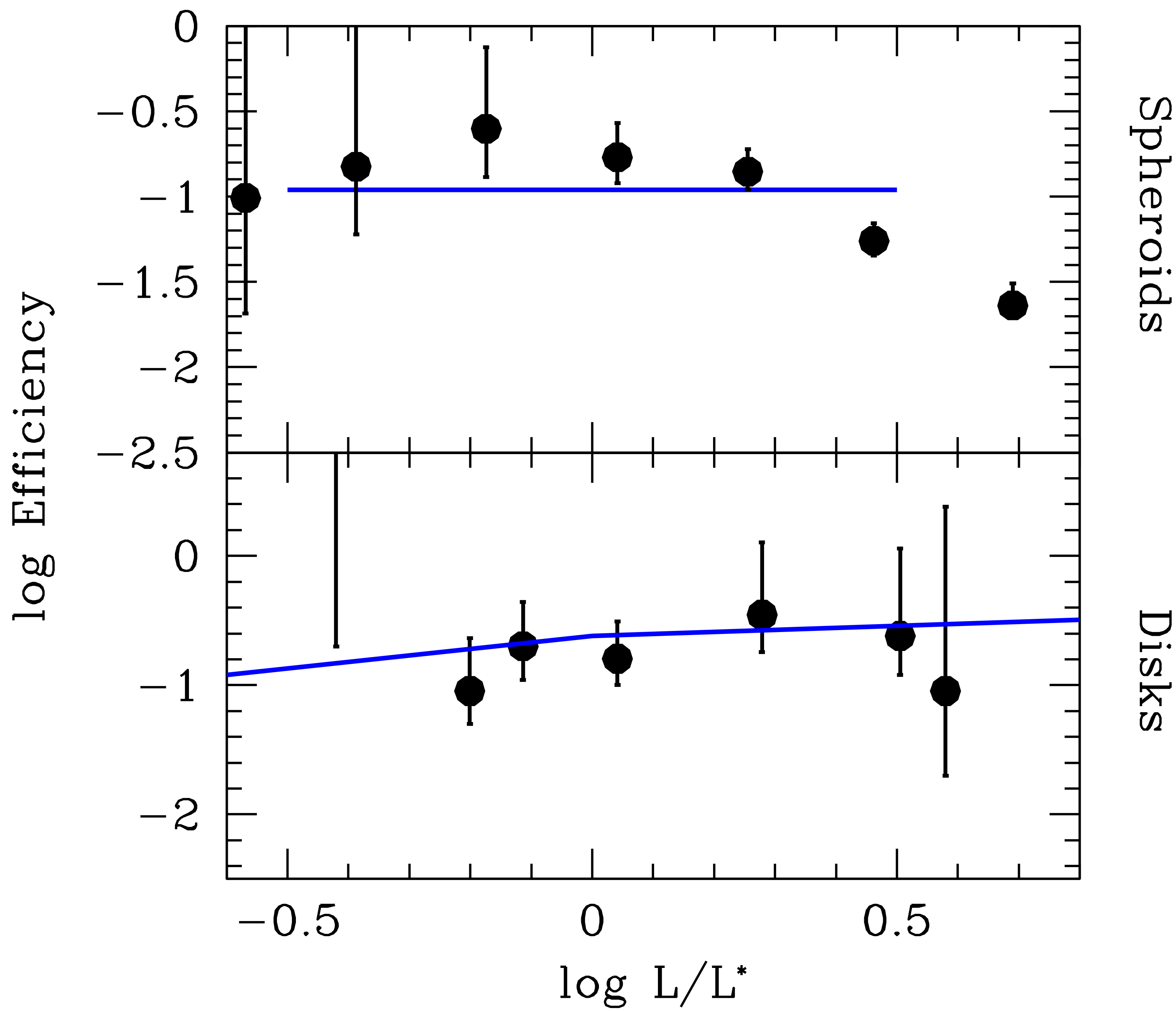
efficiency

for spheroids



$\lambda = 0.035$

efficiency ~ 0.11



Mandelbaum et al. 2006

our model

Conclusions:

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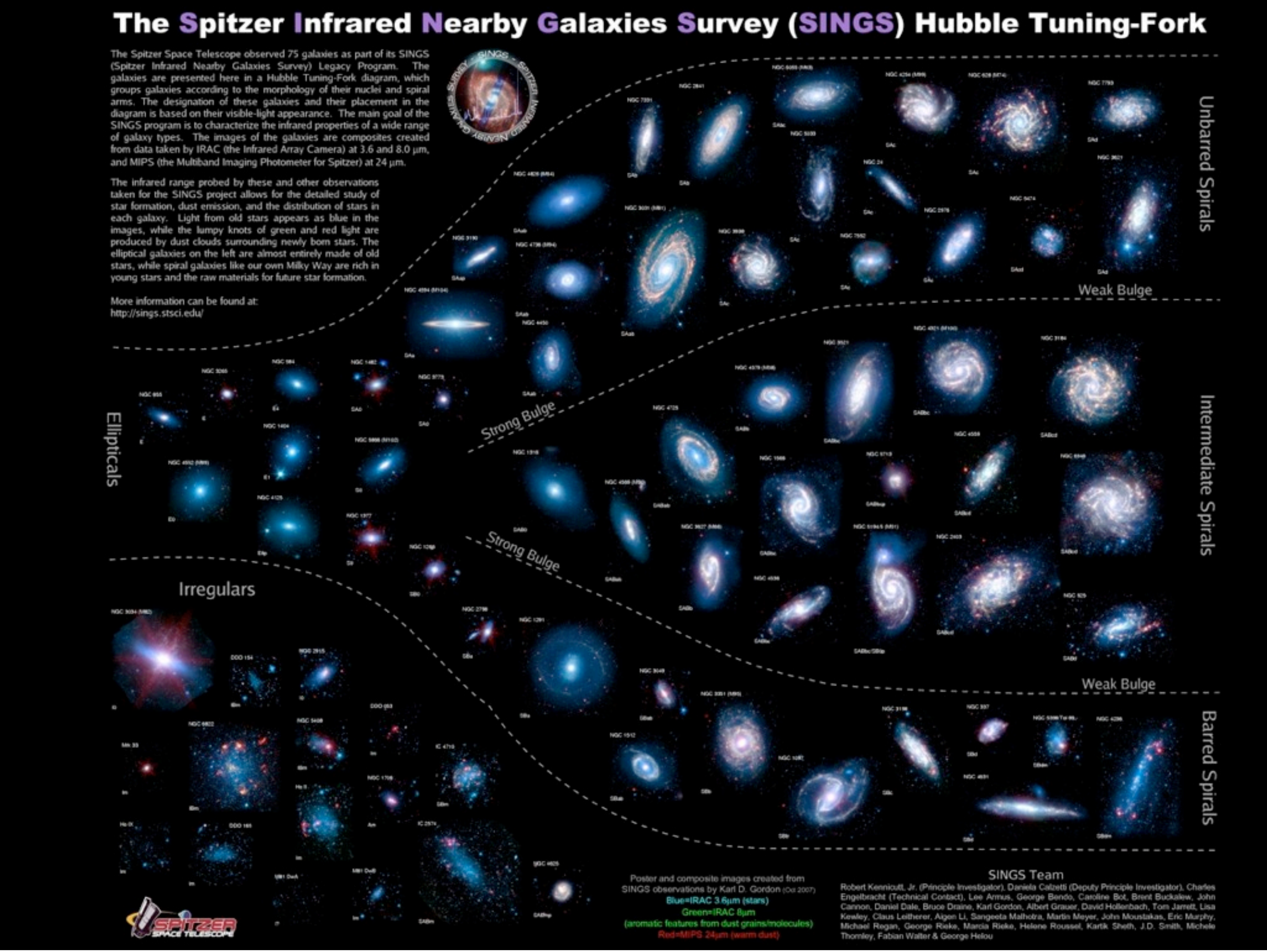
- for set profiles, simple models relate observables to halo mass and angular momentum


The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork
The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.
The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.
More information can be found at:
http://sings.stsci.edu/
Unbarred Spirals
Weak Bulge
Strong Bulge
Ellipticals
Intermediate Spirals
Strong Bulge
Irregulars
Weak Bulge
Barred Spirals
Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6μm (stars)
Green=IRAC 8μm
(aromatic features from dust grains/molecules)
Red=MIPS 24μm (warm dust)
SINGS Team
Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou
SPITZER SPACE TELESCOPE